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ANALYSIS OF EFFECT OF THE LOAD FORCE FOR A BEVEL GEAR TOOTH HAVING STRAIGHT DIRECTION

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ABSTRACT

Knowing of the geometric designing process of a straight bevel gear we have worked out a computer aided software with which this designing process could be eased. We have designed some bevel gear pairs having concrete geometry in the function of the modification of the number of teeth of the pinion and created the CAD (Computer Aided Designing) models of these gear pairs. After that the TCA (Tooth Contact Analysis) analysis could be followed. The load force have been situated on the top of the tooth edge on the tip circle. The established normal stress, normal elastic strain and normal deformation could be analyzed. Based on the results we can create the necessary diagrams and define the conclusions.

Keywords: bevel gear, tooth, TCA, CAD, normal, pinion

1. INTRODUCTION

The bevel gear pair is widely used in the mechanical constructions. We can use it in the vehicles, robots, working machines, logistics devices, etc. (Figure 1).

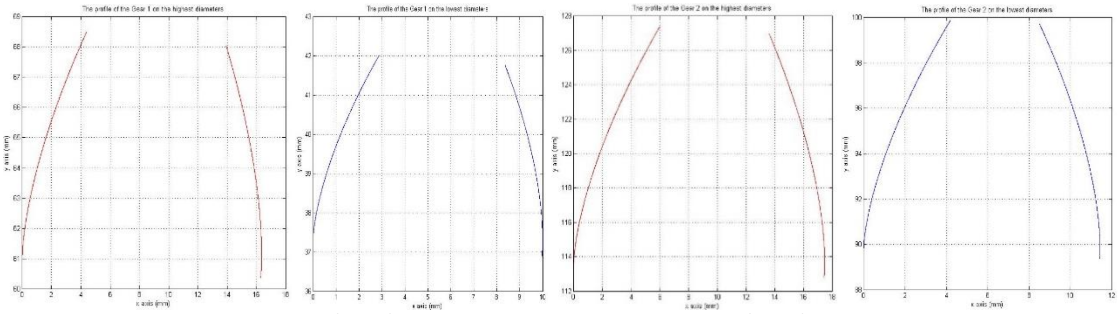
Figure 1. Car drivetrain by bevel gear pairs [12]

The main properties of bevel gear is the high load transmission, the changing of shafts' positions and directions [3, 6, 10, 11, 13].
Only one crown wheel is belonged to one geometrical corrected bevel gear pairs [3, 10, 11]. The tooth surface of the crown wheel is created the teeth of the bevel gear by wrapping [3, 10, 11]. One of the bevel gear element is rolled down on one side of the crown wheel and another bevel gear element is rolled down on the other side of the crown wheel. During production the crown wheel is created by the relative motion of the cutting tool in comparison with the bevel gear [3, 6, 7, 10, 11].

2. GEOMETRIC DESIGNING

According to the references [1, 3, 4, 5, 6, 7, 8, 9, 10, 11] we have worked out a computer software with which the geometric parameters of the bevel gears could be determined (Figure 2) [2].

Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019



a) tooth profiles of the pinion b) tooth profiles of the driven gear

Figure 2. Determination of the tooth profiles in case of the lowest and the highest diameters (m=10, z1=22, z2=30)

The output parameters of this software are the calculated geometric parameters and the tooth profiles on the lowest and the highest diameters [2]. Knowing of this parameters and the mathematical background the CAD models and the assembly of the gear pairs could be created [2].
We have designed five types of straight bevel gear. We have modified the number of teeth of the pinion. The other parameters are the same. The main input parameters of the designing process could be seen on Table 1. The calculated parameters are contained on the [2] reference.

Table 1. The input parameters of the designing of bevel gear

The main parameters of the bevel gear pairs	***Gear drive I.***	***Gear drive II.***	***Gear drive III.***	***Gear drive IV.***	***Gear drive V.***
Number of teeth of the pinion (z_1)	20	21	22	23	24
Number of teeth of the driven gear (z_2)	30				
Module (m) [mm]	10				
Bottom clearance (c^*)	0.2				
Pressure angle (α_0)	20				

Figure 3. The CAD model of a designed bevel gear pair (m=10, z1=22, z2=30)

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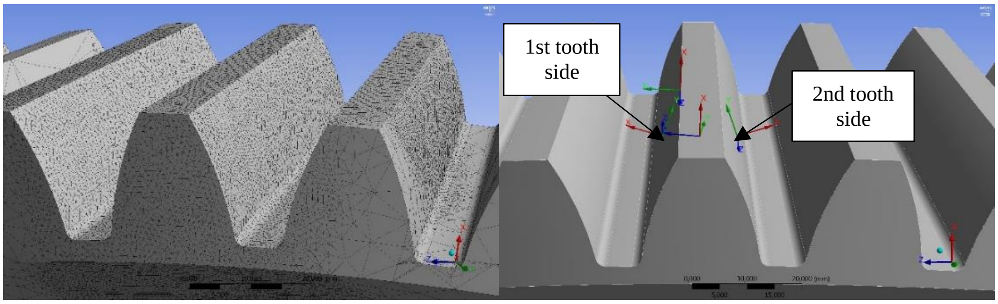
3. TCA OF THE LOADED TOOTH

The aim of the TCA is the analysis of the gear teeth by a finite element software [1, 2, 5, 8, 14]. The production is very expensive that is why many analysis have to be done before the production. Using of the TCA many mechanical parameters (stress, deformation, etc.) could be analyzed because of the goodness of the designed gear pair.

During the analysis the teeth of the driven gear have been loaded and analyzed in the function of the modification of the number of teeth of the pinion. The accuracy of the TCA's calculation is influenced by the accuracy of the finite element mesh. In this analysis the mesh density has been 1 mm around the analyzed tooth. The mesh type is triangular. One coordinate system has been adopted in the center of the tooth. Sphere meshing has been used around the analyzed tooth which center point is the center point of the adopted coordinate system. The sphere radius has been selected for 40 mm (Figure 4.a).

Two coordinate systems have been adopted on the middle of both sides of the tooth surfaces. The x directions have been the normal directions because they have been set perpendicularly to the tooth surfaces (Figure 4.b).Another coordinate system has been adopted on the middle of the edge of the tip circle.



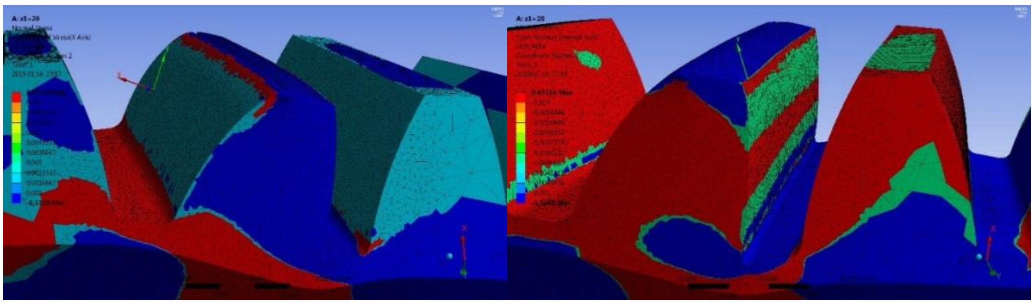
a) b)

Figure 4. The adoption of the finite element mesh and the necessary coordinate systems of the tooth of the driven gear

We have loaded the teeth of every designed driven gears (Table 1) by 100 N, 300 N and 500 N load forces. The direction vector of the loaded force is closed 45° with the vertical y coordinate axis.

The type of the material is structural steel [2].

3.1. Normal stress analysis



a) 1st tooth side b) 2nd tooth side

Figure 5. Normal stress distributions (z1=20) in case of F=100 N load force

The normal stress is analyzed on the two tooth surfaces in case of every driven gears (Figure 5).

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The normal stresses of the 1st tooth side is periodically changed (Figure 6). The lowest stresses have been established in case of 21 number of teeth of the pinion.
The normal stresses of the 2nd tooth side is continuously increased (Figure 7). The lowest stresses have been established in case of 20 number of teeth of the pinion. These values are defined in absolute value.

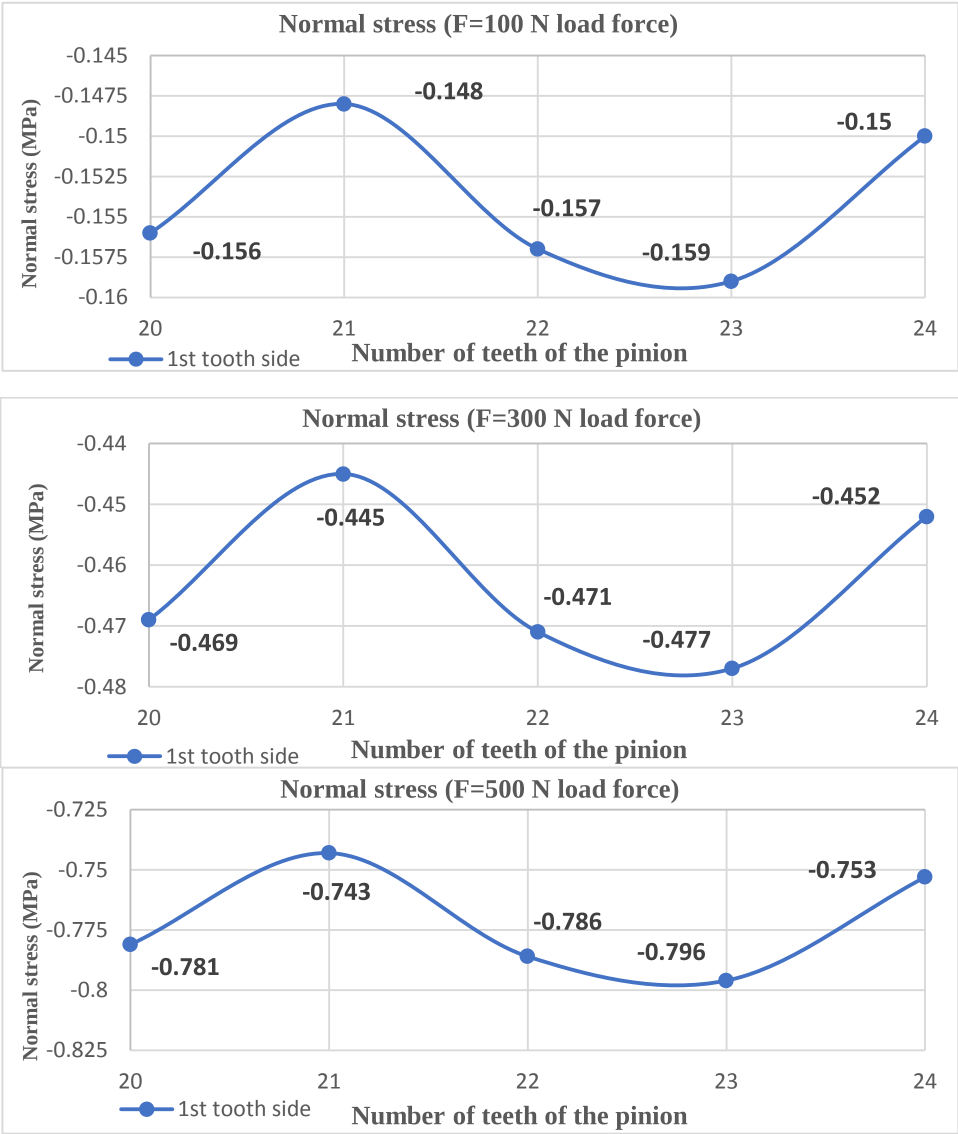
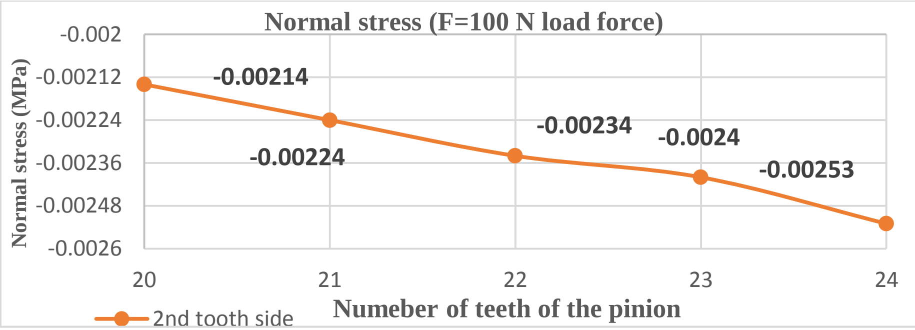
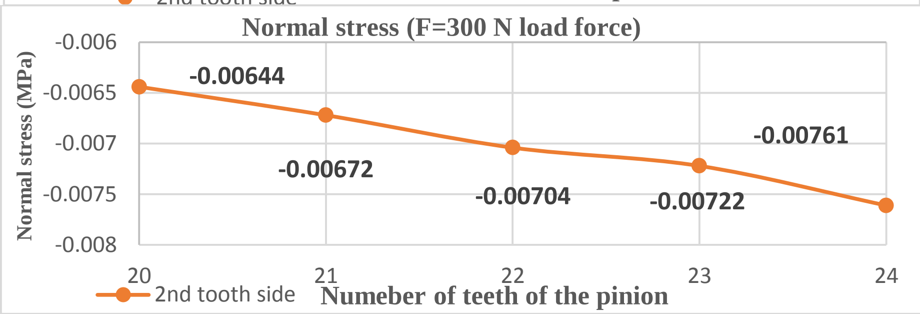


Figure 6. Normal stress results in the function of the number of teeth of the pinion (1st tooth side)





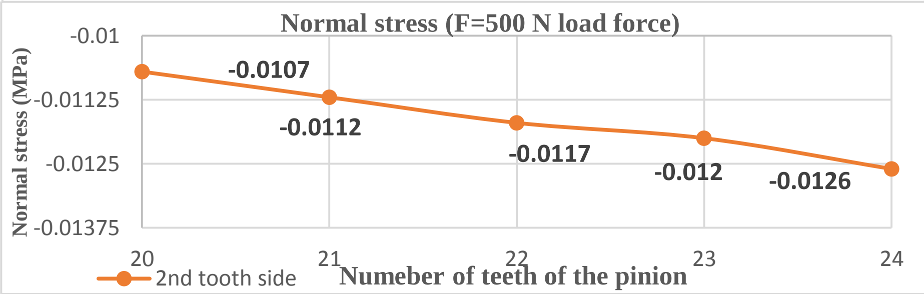
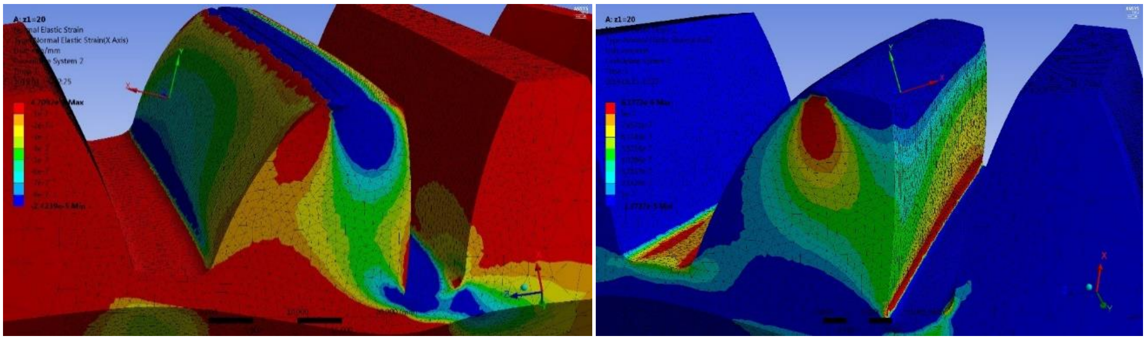


Figure 7. Normal stress results in the function of the number of teeth of the pinion (2nd tooth side)

3.2. Normal elastic strain analysis



a) 1st tooth side b) 2nd tooth side

Figure 8. Normal elastic strain distributions (z1=20) in case of F=100 N load force

The normal elastic strain is analyzed on the two tooth surfaces in case of every driven gears (Figure 8).

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The normal elastic strain of the 1st tooth side is periodically changed (Figure 9). The lowest stresses have been established in case of 21 number of teeth of the pinion.

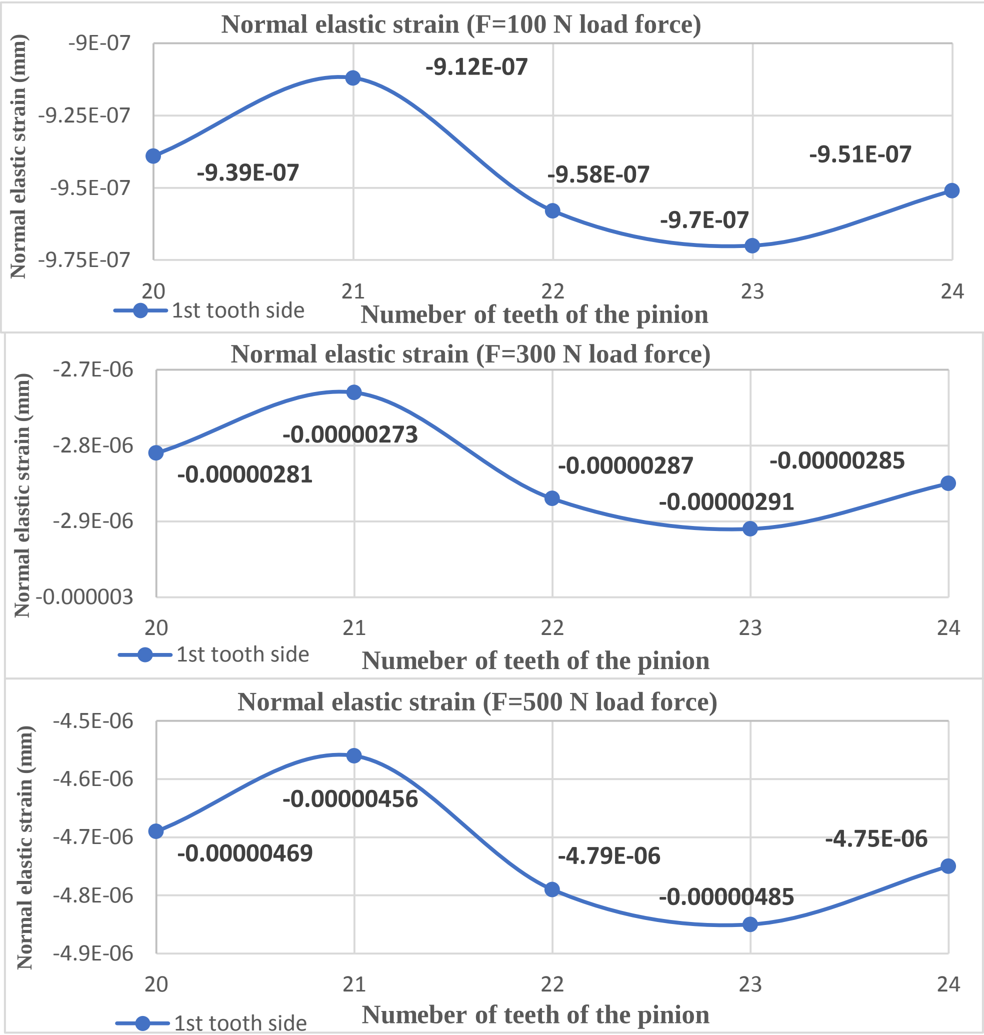

Figure 9. Normal elastic strain in the function of the number of teeth of the pinion (1st tooth side)

The normal elastic strain of the 2nd tooth side is continuously increased (Figure 10). The lowest stresses have been established in case of 20 number of teeth of the pinion. This statement is valid independently from the value of the load force (Figure 10). These values are determinable in absolute value.

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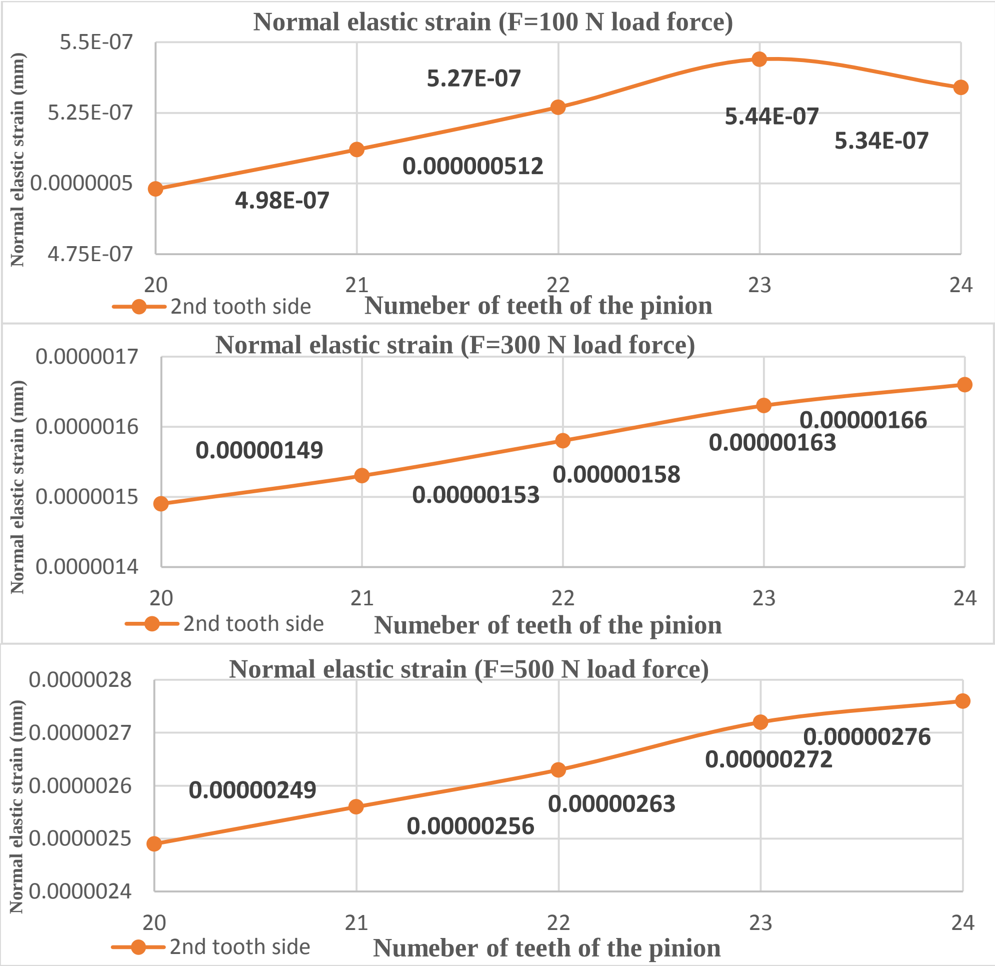
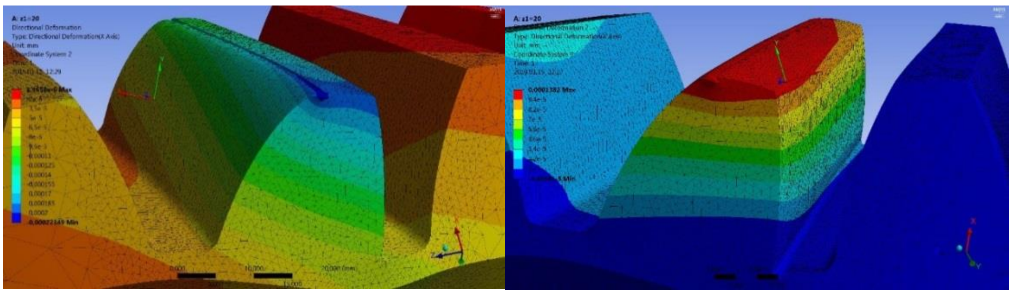


Figure 10. Normal elastic strain in the function of the number of teeth of the pinion (2nd tooth side)

3.3. Normal deformation analysis



a) 1st tooth side b) 2nd tooth side

Figure 11. Normal deformation distributions (z1=20) in case of F=100 N load force

The normal deformation is analyzed on the two tooth surfaces in case of every driven gears (Figure 11).

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The normal deformation of the 1st tooth side is progressively decreased (Figure 12). The shape of the curve is a half parabola. The lowest deformation have been established in case of 24 number of teeth of the pinion.
The normal deformation of the 2nd tooth side is continuously increased (Figure 13). The lowest stresses have been established in case of 20 number of teeth of the pinion. These values are determinable in absolute values.

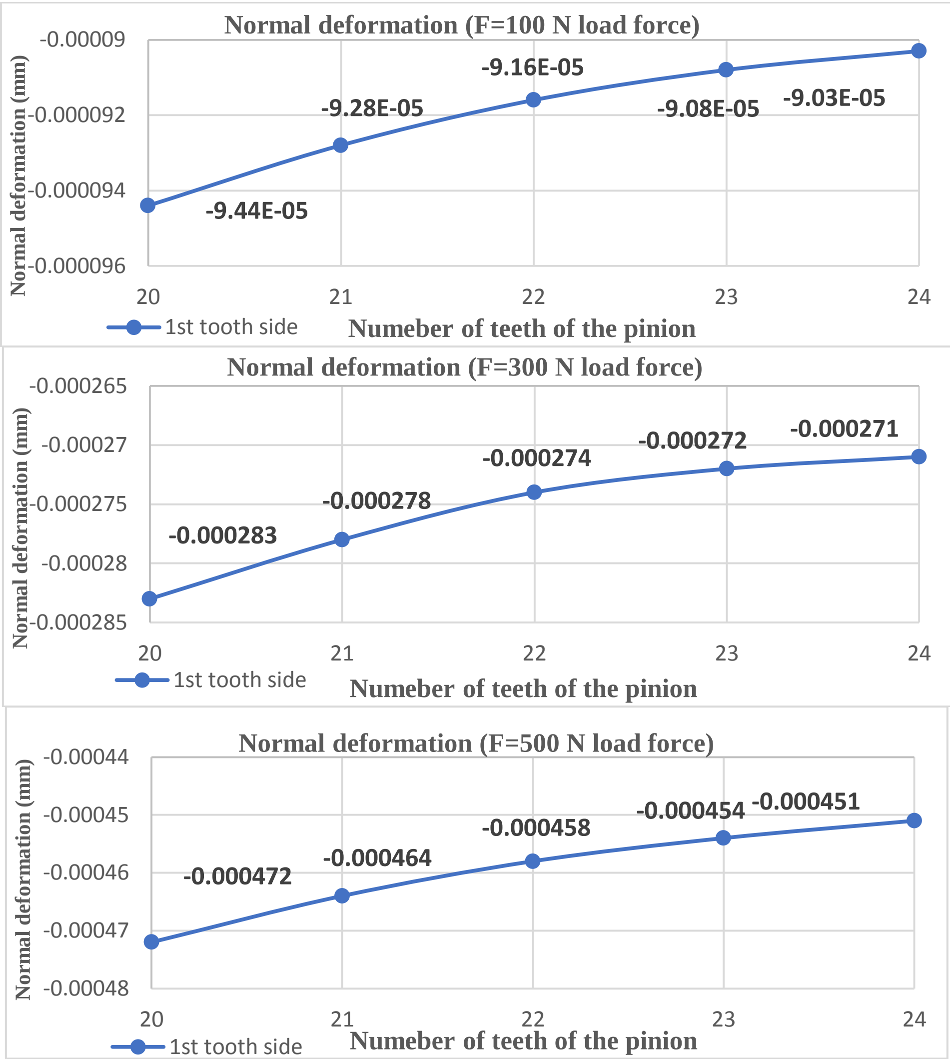

Figure 12. Normal deformation in the function of the number of teeth of the pinion (1st tooth side)

Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

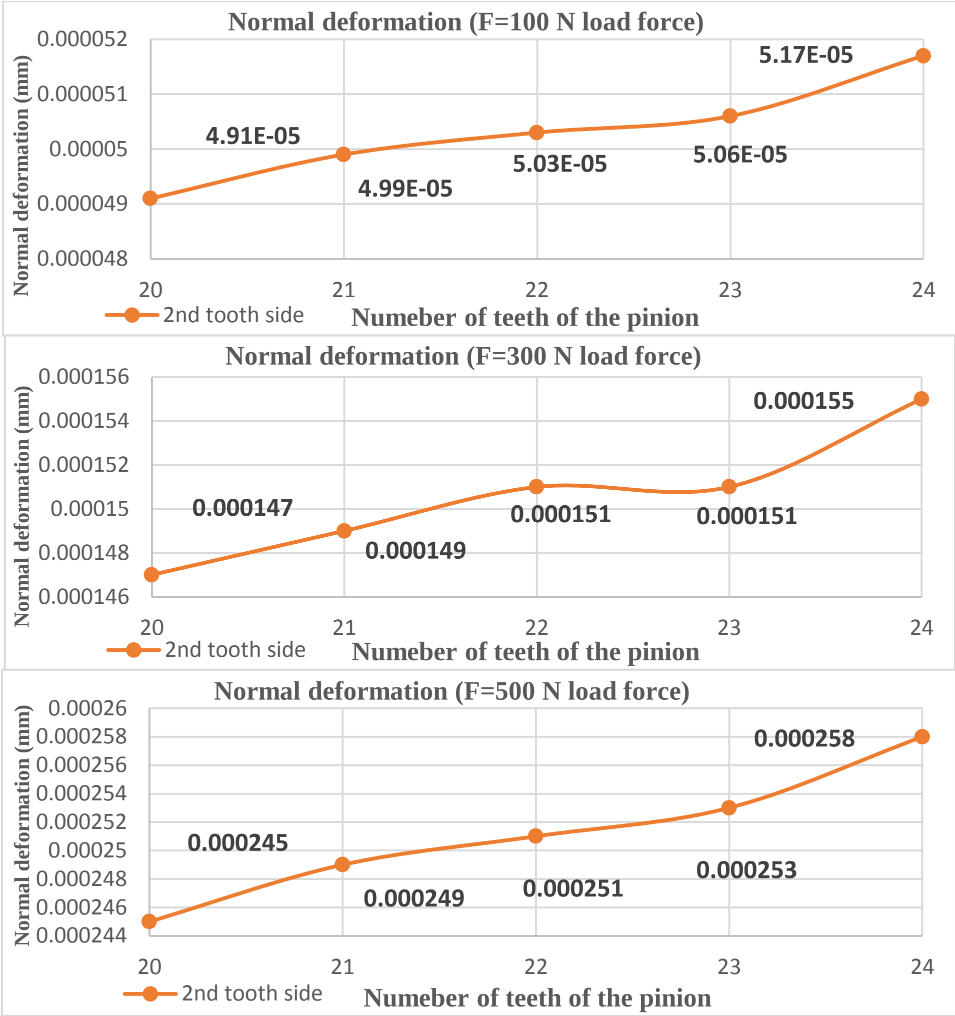

Figure 13. Normal deformation in the function of the number of teeth of the pinion (2nd tooth side)

4. CONCLUSIONS

Knowing of the mathematical calculations and the geometric formulas we have designed five different straight bevel gear pairs in the function of the modification of the number of teeth of the pinion. We used our developed computer aided software for the determination of the geometric parameters and the tooth profiles on the highest and the lowest diameters. After that the CAD models of the gear pairs have been created.

The area of the TCA is a very important research field in the gear research field. The connection and motion analysis of the connecting elements could be realized before the real production. During the analysis if a problem is occurred in the connection zone the gear geometry could be modified that is why the TCA could be started again.

We have loaded the teeth of the driven gear by different load forces. We have analyzed the TCA results in the function of the number of teeth of the pinion and the load force. The appropriate selection of the finite element mesh and the position of the load force are significantly influenced the analyzed process. We have created the necessary functions for the evaluations. Knowing of the shapes of the functions we could evaluate the results and define the conclusions. The optimum purpose is depended on the selected TCA parameter which we want to optimize in case of gear designing.

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Analecta Technica Szegedinensia

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A YIELD STABILITY INDEX AND ITS APPLICATION FOR CROP PRODUCTION

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ABSTRACT

A good crop production technology should provide high yields under varying environmental conditions, i.e. keep yield fluctuations small. The magnitude of fluctuations is usually measured by statistical indicators of average dispersion, e.g. the standard deviation. However, while many small fluctuations are usually well tolerated by the farmer, an extreme yield may be a serious risk factor. The present research introduces a yield stability index developed which measures the frequency of extremely high and extremely low yields. The index is tested for 10 countries and 18 crops for 2004-2016, comparing it to 1961-2000, pointing out possible agricultural policy implications.

Keywords: crop yield, fluctuation, risk, time series, yield stability

1. INTRODUCTION

Agriculture – and especially crop production – is very sensitive to weather and other environmental impacts. The efficiency of production technology is measured by crop yield per area, but this is considerably influenced by environmental conditions, anomalies, unexpected stressful events. Therefore yields fluctuate year by year, and the applied technology should be prepared to mitigate adverse environmental impacts. Therefore, with a proper technology the yield fluctuations due to environmental changes is are modest, while an unsuitable technology may result in very low yields even under usual, but unfavourable environmental conditions. Climate change will have a substantial effect on agricultural production. The changing precipitation and heat effects, and especially the increased frequency of extreme weather events may lead to increasing instability of crop yields and require specific technologies to maintain stable food provisions [1].

A proper crop growth technology should be capable of providing reasonably high and stable crop yields under any weather, i.e. it should be prepared to handle dry and wet periods, higher and lower temperatures, and provide reasonable protection against the typical pests or diseases that usually occur in the area of production. At the same time, technological development is expected to result in an increasing trend of crop yields, with annual fluctuations around the trend according to annual environmental variability. The purpose of crop variety selection is to find a variety that produces high yields with sufficient stability in the target environment [2]. To capture both traits Kamidi [2] created a complex index multiplying a measure of the yield performance by a measure of the variability. While the increasing trend of the yields is a welcome fact, the annual fluctuations present a risk for producers. Too low yields clearly lead to low incomes and economic losses instead of a solid profit, but extremely high yields may also have a negative economic impact. With high outputs the market supply may increase well above demand, leading to falling prices and ultimately to low incomes, in spite of high yields, if proper storage facilities are not available at reasonable costs. The association of high yields and lower producer prices was demonstrated by Kovářová et al. [3] regarding sugarbeet production in the Czech Republic, and by Kovářová and Procházková [4] for milk yield and milk price fluctuations, as well as milk turnover changes for 2006-2011.

Tóth-Kaszás et al. [5] analysing emphasise the importance of producer risk aversion as a typical characteristic of small-scale farmers. The crucial issue for them is to find a local market for their products. But demand is limited, therefore overproduction obviously leads to difficulties of sales, and thus, difficulties in achieving profitability.

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The best protection against risks generated by yield instability could be a production technology that provides reasonably stable yields under any weather and environmental conditions typical for the area. Therefore no extremes – high or low – are experienced, the producer can safely plan for the future. The question is how to define the „reasonably stable" yield, i.e. when can the yield fluctuations around the increasing trend be considered „reasonably small". The fluctuation of the time series around the trend is usually measured by various dispersion indicators. The sum of the absolute errors (the absolute value of the difference between the actual value and the trend estimation), the sum of squares of error, the standard deviation, the coefficient of variation (the standard deviation divided by the mean value) are generally used, as is described in any introductory statistical text (see e.g. [2]).

Literature is abundant on assessing intertemporal crop yield stability, or more generally the variability of time series data. The most commonly used method to assess stability is the standard deviation of the data, i.e. the standard deviation of crop yields, although other methods are also used, e.g. the average percent deviation from a trend, either linear or non-linear [7].

Yield stability analyses have been aimed to find the highest yielding varieties, or cropping systems, that are not varying intolerably with changing environmental conditions. However, high yields often go together with higher yield variability. Yield variability can be measured at the level of individual crop varieties, and also at the aggregate national level, i.e., the average yields of all varieties of a given crop grown in a certain area.

According to Piepho [8] cropping systems are considered stable when some variance component is small. However, assessing the risk of a poor yield may be more important than general yield stability, as producers can usually better accept systems that produce high average yield with larger yield variance, than lower yielding systems with small yield variance. Therefore yield stability assessments should consider both the mean yield and yield variance. Piepho [8] emphasises the fact, that measuring the risk of a decreasing yield may be more useful than a quantification of the general level of yield variance. Yield stability measures based on regression fitted to yield series are widely used, with instability measured as the mean square deviation from the regression model [9].

Khalil and Pour-Aboughadareh [9] compare various barley cultivars, assessing their adaptability to specific natural conditions. High adaptability requires high mean yields across environments, with little variability or deviation from the mean yield. They use the coefficient of variation and the sum of squares of deviations around a regression line as measures of variability. Maize experimental data were used by Wang et al. [10] assessed yield variability for paddy rice, maize, wheat and rapeseed over the period 1952-2009 in Yunnan province, China. They determine the trend of each crop yield series, and compute the proportion of the residual values to the estimated trend values. They consider negative residual values as various levels of disaster, but do not consider positive residuals problematic in any sense. Similar trend-based studies were carried out for for the USA and Western Europe in [11-13] and [14].

However, as Bacsi and Vizvári [15], and Vizvári and Bacsi [16] pointed out, a high standard deviation may be the result of a few very extreme fluctuations, but also of many much smaller fluctuations. For a farmer the two situations are completely different. The many small fluctuations in crop yields are well within the range of acceptable variability which the producer can handle, while a few extremely low, or high, yields may create serious economic risk. Bacsi and Vízvári [15] developed a yield risk index which measures the frequency of extremely high or extremely low yields in a time series.

A modified version of this index is the yield stability index [16], which quantifies the level of stability for a yield series, by measuring the proportion of annual yields being reasonably close to the expected trend value within a time period. The two indices – the yield risk index and the yield stability index - were tested for 10 countries and 18 crops for the time period 1961-2000 [15],[16].

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The total world production of these crops is significant, they covered 85% of the crop area in Europe, and 64% in the world in 2010. The present paper, adjusting somewhat the yield stability index, carries out the same analysis for the same crops and countries for the period 2004-2016 with two purposes. One of these is to see the changes in the stability of the crop production, with consideration of climate change and the changing agricultural policies of the EU. The other purpose is to demonstrate the practical relevance and applicability of the yield stability index for the agricultural policy of a country.

2. MATERIALS AND METHODS

The methodology of computing the yield stability index is described in detail in Vizvári-Bacsi [16], the yield risk index is explained in Bacsi-Vízvári [15]. The essence of the calculations, with the proposed adjustments, is briefly summarised below.

Taking a country and a particular crop, annual yields are measured for a given period of years. The trend of these yields is determined by fitting a linear regression equation to these annual yield series (a non-linear trend may as well be fitted if the series justify it better). Then, the fitted line is used to estimate expected yields for each year, and the differences between the expected yield and the actual yield are computed. The core of the analysis is to evaluate these differences, and decide, whether they are large, or tolerably small. However, the differences depend on the general magnitude of the yield series, therefore the 1000 kg/ha difference can be small for sugarbeet, with a typical yield around 60000 kg/ha, while it is very high for rye having a typical yield of about 3000 kg/ha.

In order to make crops and differences comparable, the yield time series were normalised in the following way. Before fitting the trend line each time series is divided by its average value, therefore the normalised time series show the proportion of the actual yield to the average yield of the crop. Then the trend lines are fitted to these normalised series, and the expected normalised yield values are computed. Annual normalised yield residuals are computed as the difference between the normalised value of the actual yield and the estimated trend value computed from the normalised trend equation. This way each residual is measured relative to the magnitude of the actual time series, and thus various crops and countries are made comparable regarding the largeness or smallness of yield fluctuations.

The residuals should be assessed whether they are „small” or „large”. For this purpose the normal distribution is used to determine the „tolerably small” and „too large” values. The parameters of the normal distribution are the same as of the residual series (zero expected value and standard deviation of the residual series). Using this normal distribution the residuals are small if at least as many residual values fall in the „vicinity of zero” as is the case for the normal distribution, and therefore less of the residual values fall „far from zero” as for the normal distribution. To define the „vicinity of zero” the range of the normalised residual series is divided into 10 equal intervals. The value of 0 falls into one of the middle segments, usually into the 5th or 6th one. The „vicinity of zero” is defined then as the 4 middle segments, while the 3 lowest and the 3 highest segments are „far from zero”.

Because for each crop the yield series of 10 countries were used in the analysis, the minimum and maximum values of the residuals were taken as the minimum and maximum of the 10 countries, for a particular crop. Thus the same range and segments were defined for each country for this crop. Similarly, the standard deviation for the normal distribution of a particular crop was the average of all the residual standard deviations of the 10 countries for this crop, thus the same normal distribution was used for each country for the particular crop.

The final step is to compare the residual distribution and the normal distribution. Taking the proportion of the 13 normalised residual values falling into the four middle segments (FRF – favourable residual frequency, the values in the vicinity of zero), and similarly, the proportion of values from the normal distribution that would fall into the four middle segments (FNF – favourable normal frequency), we can compute the sum of favourable differences (FD) as FD = FRF-FNF.

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Then the proportion of the normalised residual values not falling into the four middle segments (URF – unfavourable residual frequency, values far from zero) and the proportion of the normal distribution not falling into the four middle segments (UNF – unfavourable normal frequency) give the sum of unfavourable differences (UD) as UD = URF-UNF. Note, that FRF+URF=1 and FNF+UNF=1, thus UD =URF−UNF=1−FRF−1+FNF=FNF−FRF= − FD. The adjusted yield stability index is computed as YSI = FD−UD =2 × (FRF−FNF).

The yield stability index defined by Vizvári and Bacsi [16] counted with absolute numbers instead of proportions, therefore the index values depended on the length of the time period analysed. The yield risk index *YRI* [15] applied a division by the length of the data series, which gives the same result as using proportions. The yield risk index used signs opposite as the yield stability index, therefore YRI = − YSI. As YSI=2 × (FRF−FNF), both FRF and FNF are proportion values between 0 and 1, the YSI can take values between -2 and +2, regardless of the crop and the number of years analysed. Using the above methodology the yield stability index is computed for 10 countries and 18 crops for the time period 2004-2016, based on yield data of the FAO database [17]. The following countries were chosen: Canada (CA), Denmark (DK), France (FR), Hungary (HU), Italy (IT), The Netherlands (NL), Turkey (TU), The United Kingdom (UK), USA (US) and Japan (JP). The 18 crops selected for the analysis are: barley, wheat, maize, rice, rye, oats, sunflower, rapeseed, potatoes, sugarbeet, hops, green peas, onions, cabbages, spinach, carrots, cucumbers and soybean. Results of the time period 2004-2016 were compared to the period of 1961-2000 using the results of [16], to see whether any technological progress is detectable.

3. RESULTS AND DISCUSSION

The average yields for each crop widely differ among the countries, depending on the environmental conditions and production technologies – including intensive and extensive farming (Figure 1). The 13-year average cucumber yields are 44 times higher in the Netherlands than in the USA, and spinach yields are also 4.25 times higher in France than in Denmark.

As it was described in the methodology section, the annual yield series of each country and each crop are normalised (i.e. divided by the 13-year average), and linear trends are fitted to each normalised series. Then the residual time series for each crop in each country are computed. As the normalisation process makes fluctuations comparable, these standard deviations can be used to compare the yield variabilities of crops and countries.

Taking the average of standard deviations of each crop across countries, the highest standard deviation was found for spinach in Denmark (0.517), followed by cucumber in France (0.337). For most crops and countries the standard deviation remained under 0.1. Turkey and Italy had the smallest average residual standard deviations across crops (0.063).

As described above, the residual time series of the crops in the ten assessed countries are compared to the normal distribution of zero expected value and average standard deviations of each crop. Then the occurrences of favourable and unfavourable deviations are computed, and the Yield Stability Index is determined for each crop and each country. To facilitate comparison, the YSI values for the years 1960-2000 are presented using the data of Vízvári and Bacsi [16] with the adjustments described in the methodology (Table 1), and the results for the period 2004-2016 are presented in Table 2.

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Analecta Technica Szegedinensia
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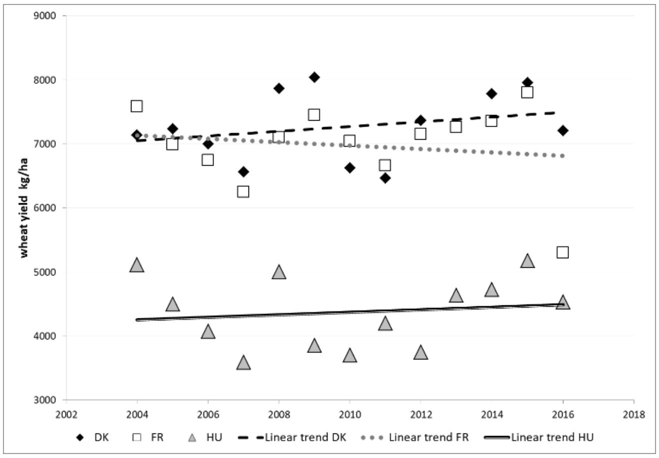

Figure 1:Annual wheat yields in Denmark, France and Hungary 2004-2016 (from data of [17])

Table 1: Yield Stability Index Values, 1961-2000
(Authors' own computations based on [16])

YSI	CA	DK	FR	HU	IT	NL	TU	UK	US	JP	*Mean*
barley	0.081	0.006	0.081	-0.245	0.006	0.056	0.031	0.081	0.081		**0.019**
wheat	-0.028	0.047	0.122	-0.303	0.072	0.047	-0.078	0.072	0.072		**0.003**
maize	0.078		0.078	0.003	0.078	-0.072	0.078	-0.297	-0.172		**-0.028**
rice			-0.088	-0.288	0.013		0.088		0.113	0.088	**-0.013**
rye	-0.004	0.046	0.121	-0.129	0.096	0.046	0.021	0.046	-0.029		**0.024**
oats	0.092	-0.083	0.067	-0.433	-0.008	-0.008	0.092	0.092	0.067		**-0.014**
sunflower	0.141		0.216	0.041	0.216		0.241		0.166		**0.170**
rapeseed	0.049	-0.001	0.024	0.024	-0.051	0.049	-0.076	0.024			**0.005**
potatoes	0.102	-0.023	-0.023	-0.198	0.102	-0.023	0.002	0.052	0.102		**0.011**
sugarbeet	0.074	0.049	0.099	-0.101	0.049	-0.001	-0.101	-0.101	0.149		**0.013**
hops	0.029		-0.021	0.104				0.204	-0.146		**0.034**
green peas	0.042	-0.008	0.042	-0.083	-0.108	0.042	0.017	0.017	-0.033		**-0.008**
onions	0.009	-0.117	-0.042	-0.317	0.184	-0.117	0.159	0.009	0.184		**-0.005**
cabbages	-0.067	-0.217	0.108	-0.242	0.083	0.108	0.083	-0.317	0.108		**-0.039**
spinach	0.112	0.012	0.062	-0.013	0.162	-0.038	0.012		-0.238	-0.063	**0.001**
carrots	0.090	-0.035	0.115	-0.110	0.115	-0.160	-0.260	-0.035	0.165		**-0.013**
cucumbers	-0.048	-0.423	-0.023	-0.148	0.077	-0.173	0.077	0.077	0.077		**-0.057**
soybean	0.088		-0.262	-0.112	0.088	0.000	-0.087		0.088	0.063	**-0.017**
Mean	**0.049**	**-0.058**	**0.038**	**-0.142**	**0.069**	**-0.016**	**0.017**	**-0.006**	**0.044**	**0.029**	

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The Yield Stability Index for the major cereals is positive for most of the countries. Hungary is the only country in which it is negative for both 2004-2016 and 1960-2000, although the maize index value is slightly improved since 2004, the EU-accession (Table 3 and Figure 2).
For France, on the contrary, YSI values decreased for barley, wheat and maize after 2004, and only rice showed a positive change. Italy has experienced a considerable improvement of YSI for all the four presented crops, yields have become more stable than they were before 2000.
Table 3 presents the changes of the yield stability computed by the following formula:

$$YSI_{change} = YSI_{(2004\text{-}2016)} - YSI_{(1961\text{-}2000)} \tag{1}$$

Positive values indicate that yields have become more stable after 2004 than they were before 2000.
In most of the countries many crops show improved yield stability, but none of the countries achieved improved yield stability for all the 18 crops. There is no crop, that has better yield stability for all the countries, but the YSI of cucumbers improved everywhere except in France, and the YSI of cabbages improved in 8 countries (the Netherlands and Japan are the exceptions). On the contrary, for sunflower the yield stability improved only in one country (Hungary), the other five producers cound not achieve higher YSI values than before 2000 (Table 3).

Table 2: Yield Stability Index Values, 2004-2016

YSI	CA	DK	FR	HU	IT	NL	TU	UK	US	JP	*Mean*
barley	0.110	0.110	0.033	-0.198	0.187	0.033	-0.121	0.187	-0.044	-0.044	**0.025**
wheat	0.176	0.022	-0.132	-0.285	0.176	0.099	0.176	0.022	0.176	-0.132	**0.030**
maize	0.233	-0.383	0.079	-0.152	0.156	-0.152	0.079		0.002	0.233	**0.010**
rice			-0.034	-0.111	0.197		0.043		0.197	0.120	**0.068**
rye	0.152	0.229	0.229	-0.078	0.152	-0.001	0.152	-0.386	0.076		**0.058**
oats	0.027	-0.049	-0.049	-0.203	0.181	-0.280	0.027	0.181	0.104	0.104	**0.004**
sunflower	-0.171		0.060	0.060	0.214		-0.017		0.060		**0.034**
rapeseed	0.141	0.141	-0.013	-0.167	-0.013	-0.167	0.218	0.141	0.064	-0.167	**0.018**
potatoes	0.032	-0.045	-0.045	-0.045	0.032	0.032	0.032	-0.199	0.263	0.032	**0.009**
sugarbeet	0.105	0.028	0.259	-0.049	-0.049	0.182	0.105	-0.280	0.182	0.105	**0.059**
hops			0.058	-0.173				-0.096	0.212	-0.404	**-0.081**
green peas	0.108	-0.200	0.108	0.031	0.031	0.108	-0.046	-0.277	-0.431	0.108	**-0.046**
onions	-0.030	0.124	-0.107	-0.107	0.201	0.047	0.124	-0.030	0.124	-0.030	**0.032**
cabbages	0.194	-0.037	0.194	0.040	0.194	-0.422	0.194	0.040	0.117	-0.422	**0.009**
spinach	-0.044	-0.506	0.033	0.033	0.033	0.033	0.033		0.033	0.033	**-0.036**
carrots	-0.390	0.072	0.072	-0.467	-0.005	-0.005	0.072	0.149	0.149	0.149	**-0.021**
cucumbers	0.027	-0.358	-0.358	0.027	0.104	0.181	0.181	0.181	0.181	0.181	**0.035**
soybean	0.128		0.051	-0.180	-0.026		0.128		0.128	-0.026	**0.029**
Mean	**0.050**	**-0.061**	**0.024**	**-0.112**	**0.104**	**-0.022**	**0.081**	**-0.028**	**0.088**	**-0.010**	

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The Yield Stability Index developed and computed here can have two main possible ways of application. One is of a methodological importance. The YSI provides a different, and better, way of assessing crop yield stability than formerly applied simple methods. It is relatively easy to compute, it differentiates between many small deviations and few large ones, and accounts for both low and high yield extremes as instability. This approach is more reasonable for farmers than using the standard deviation or coefficient of variation, because the latter two consider small and large deviations with equal importance.

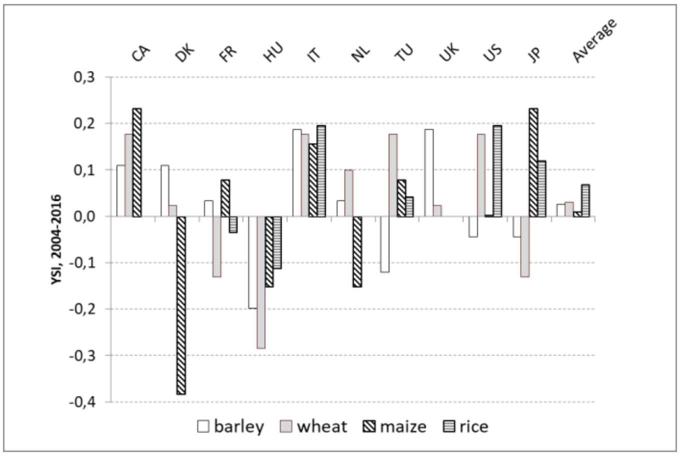

Figure 2: The Yield Stability Index Values for Selected Crops in 2004-2016 (Authors' own construction based on the data of Table 3.)

Comparing the YSI values to the coefficients of variation (CV) the two indicators give a different judgement on crop yields. The CV values are positive, and higher CV means higher variability (higher variance relative to the average) of crop yields. The YSI measures the opposite, the stability of yields, therefore higher YSI means better stability, i.e. less variability. Therefore CV and YSI should have an inverse relationship.

As is presented in Figure 3 the CV values plotted against YSI values pooling all countries and all crops (i.e. 18 x 10 = 180 value pairs) show this negative relationship, but a fitted regression line is far from showing a perfect fit. This indicates that CV and YSI often give different judgments on particular crops in particular countries. The correlation coefficient between CV and YSI is R= −0.580, which is not particularly strong, though negative. As is seen in the figure, for some crops and countries a rather low CV (low variability) is accompanied by a small negative YSI (high variability) as for carrots in Hungary and hops in Japan, or a high CV (high variability) goes together with a positive and high YSI (low variability), e.g. rapeseed in Turkey. This demonstrates the practical relevance of computing YSI, and using it instead of CV for a refined assessment of stability.

The second application is relevant for decision making purposes. This application is based on the actual computed values of YSI – which, due to the methodology, are directly comparable between countries, between time periods, and between crops. A totally unstable crop would have its YSI value near -2.0, while a very stable crop would have YSI close to 2.0. Comparing the actual computed YSI index values to these theoretical limits the stability level of a crop in a country can be directly assessed. Positive YSI values indicate that the assessed crop and its production technology are well suited to the environmental conditions of the country and the present technology can maintain the yield trends with no risk. Temporal changes in YSI show the technological changes for a crop in the country. Thus a positive change in the index indicates that research and development (R&D) directed to production technology is successful for

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the crop, and the crop production system can be better adapted to the environmental conditions of the country.

Table 3: Change of Yield Stability Index (YSI change) from 1961-2000 to 2004-2016

YSI *change*	**CA**	**DK**	**FR**	**HU**	**IT**	**NL**	**TU**	**UK**	**US**	**JP**	***Mean***
barley	0.029	0.104	-0.048	0.047	0.181	-0.023	-0.151	0.106	-0.125	-0.044	**0.008**
wheat	0.204	-0.025	-0.254	0.018	0.104	0.052	0.254	-0.050	0.104	-0.132	**0.028**
maize	0.155	-0.383	0.001	-0.155	0.078	-0.080	0.001	0.297	0.174	0.233	**0.032**
rice			0.053	0.177	0.184		-0.045		0.084	0.032	**0.081**
rye	0.156	0.183	0.108	0.050	0.056	-0.048	0.131	-0.432	0.104		**0.034**
oats	-0.065	0.034	-0.116	0.230	0.190	-0.272	-0.064	0.089	0.037	0.104	**0.017**
sunflower	-0.311		-0.156	0.019	-0.002		-0.258		-0.106		**-0.135**
rapeseed	0.092	0.142	-0.037	-0.191	0.038	-0.216	0.294	0.117	0.064	-0.167	**0.013**
potatoes	-0.070	-0.022	-0.022	0.153	-0.070	0.055	0.030	-0.251	0.161	0.032	**0.000**
sugarbeet	0.031	-0.021	0.160	0.052	-0.098	0.183	0.206	-0.179	0.033	0.105	**0.047**
hops	-0.029		0.079	-0.277				-0.300	0.358	-0.404	**-0.096**
green peas	0.066	-0.192	0.066	0.114	0.139	0.066	-0.063	-0.294	-0.397	0.108	**-0.039**
onions	-0.039	0.240	-0.065	0.210	0.017	0.163	-0.035	-0.039	-0.060	-0.030	**0.036**
cabbages	0.261	0.180	0.086	0.282	0.111	-0.530	0.111	0.357	0.009	-0.422	**0.044**
spinach	-0.156	-0.517	-0.029	0.046	-0.129	0.071	0.021		0.271	0.096	**-0.036**
carrots	-0.480	0.107	-0.043	-0.356	-0.120	0.155	0.332	0.184	-0.016	0.149	**-0.009**
cucumbers	0.075	0.066	-0.334	0.175	0.027	0.354	0.104	0.104	0.104	0.181	**0.085**
soybean	0.040		0.313	-0.068	-0.114		0.215		0.040	-0.089	**0.048**
Mean	**-0.002**	**-0.007**	**-0.013**	**0.029**	**0.035**	**-0.005**	**0.064**	**-0.021**	**0.047**	**-0.015**	**0.013**

However, the actual YSI and the change of YSI both may be important for decision makers. A positive YSI and a positive change of YSI means, that the crop and its production technology are well adapted to the environment, and there are possibilites of further improvement. Then this crop is a prospective success in the particular country. On the contrary, a negative, and decreasing YSI means that the crop is not suitable, and improvement cannot be seen, therefore either the crop should be abandoned as too risky, or a profound change of the technology should be introduced.

With negative but increasing YSI a formerly less well adapted production technology seems to be improved, and development goes hopefully in the right direction. The situation, when YSI is positive but decreasing should raise the attention of decision makers. The current technology is still suitable, but the risk of higher variability is increasing, therefore an improvement for the technology must be looked for. In an extreme case, this tendency may indicate that long-term climate change makes a formerly well adapted crop unsuitable in the future. These possibilities should be taken into account when deciding about cropping structures and R&D directions.

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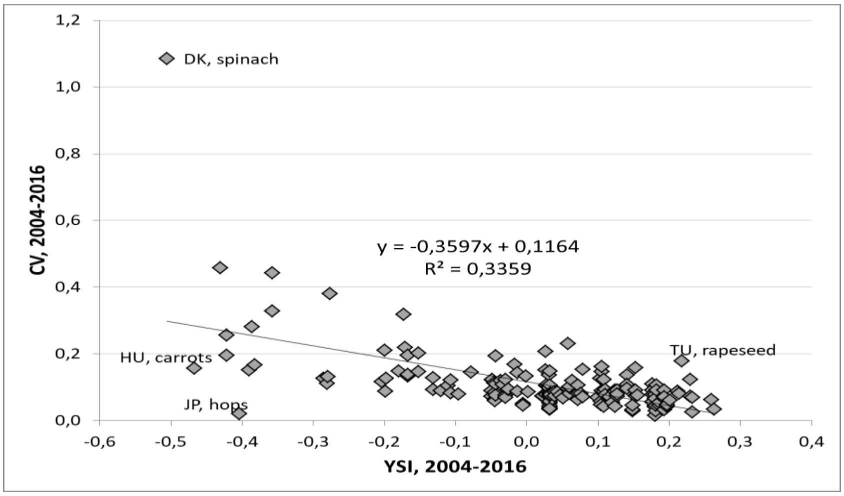

Figure 3: The Coefficients of Variation and YSI for all countries and all crops in 2004-2016.

4. CONCLUSIONS

The yield stability index measures only deviations of yields from the yield trend, but it does not say anything about the actual level of the yield, or the direction of the trend (increasing or decreasing). Therefore, for decision makers both the trend of the yields, and the YSI value should be taken into account. The optimal cropping technology should have high yields (high slope of a yield trend) with low variability (high YSI).

This may have an implication for the agricultural support policies of countries. Countries with a general support scheme for agricultural producers can provide a protection against risk for the farmers. Intervention schemes for overproduction or insurance structures against very low yields may make the agricultural sector less sensitive to the possible risks related to yield variability, and this may decrease the sector's motivation to improve production technologies. Public subsidies fro the farming sector are very influential both in the USA and in the EU [13]. Although this aspect was not researched in this paper, four of the six assessed EU-member states produced negative average changes in YSI values (Italy and Hungary were the only countries with positive average change). The highest stability improvements were seen in the USA and Turkey, although probable causes or explanations are beyond the scope of the present paper. With decreasing agricultural support the farmers in the EU will have to be more conscious of introducing risk-mitigating technologies.

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DIGITAL FACTORY IN THE UNIVERSITY OF PANNONIA NAGYKANIZSA CAMPUS — THE FACTORY SUBSYSTEM

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ABSTRACT

One of the new challenges of the 21st century is the Industry 4.0. Manufacturing companies moving away from mass production and getting closer to customized production and manufacturing of customized products through digitization. The expectations are high, meeting the requirements is a real challenge to industrial partners. In order to help meet the challenges the University of Pannonia Nagykanizsa Campus started to establish a fully automatized industrial laboratory. In this paper the architecture of the Industry 4.0 laboratory and the purpose of the Factory Subsystem is presented.

Keywords: Industry 4.0; digital factory; innovation, communication

1. INTRODUCTION

Digitization, the deployment of information technology and automation have great impact in manufacturing industry and manufacturing companies. The operation of manufacturing companies has changed significantly, it is switched from mass production to customized products and production. Industry 4.0 strategy includes several key technologies to digitize production flow or even the whole supply chain. The University of Pannonia Nagykanizsa Campus is establishing an Industry 4.0 laboratory. The goal of the laboratory is to cover most areas of factory digitalization.

Not only the production but the entire supply chain, i.e. from acquisition to customer services, will be modelled in the laboratory. It requires the integration of different research areas and technologies e.g. adaptive systems, data mining, machine learning, optimization, protocol technology, sensor and computer networks. These key technologies may provide to model the main elements of the fully automated industrial processes that leads to efficiency gains and allows to produce highly customized product at small lot size.

In this paper the structure of the laboratory is presented and the role and functions of its Factory Subsystem is described in details. The paper is organized as follows. Section 2 describes Industry 4.0 and learning factory concepts. In Section 3 problem statement is presented. Section 4 presents the system plan of the laboratory. Section 5 introduces the Factory Subsystem. The last section concludes the paper.

2. INDUSTRY 4.0 AND LEARNING FACTORIES

Nowadays we are facing of the next industrial revolution, so-called Industry 4.0. The term Industry 4.0 has been introduced by the German government. The complexity of manufacturing systems and the need of customized products yield to the digitalization of the production. The digitalization cannot be realized effectively without computerization. The continuous evolution of information technology like Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS), robotics, cloud- and cognitive computing, big data and augmented reality (AR) results significant change in production systems [1] [2].

The concept of the Industry 4.0 digitalizes the whole supply chain to be able to make fully customized products [3]. This approach is used worldwide but some countries use different terms. For example, in the USA it is called “reindustrialization” of the manufacturing industry, in Japan “New Robot Strategy” for producing cooperative robots, in China “Made-in-China 2025”, in France ‘New Industrial France”, in UK “high-value manufacturing” and in South Korea “advanced innovators’ strategy” [4] [5] [6] [7] [8].

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The Industry 4.0 is a widely researched area, systematic literature reviews are frequently published [5] [9] [10] [11]. Most research papers in this area are mainly focused on the technological aspects [12] [13] [14] but the human operators also are important part of the production systems [15] [16] [17] [18] [19]. The newest development of IoT devices has the possibility to design machines which can replace human minds [20].

Numerous papers exist about learning factories focusing on Industry 4.0. These factories have different look and purpose and they demonstrate different implementation aspects [21] [22] [23] [24] [25]. There are reviews demonstrating the existing approaches of learning factories available in academia and industry [26] [27] [28] [29].

3. PROBLEM STATEMENT

The technology is developing continuously by humanity. Many important breakthroughs were seen in the past. But none of them was as important as that is now in progress. It has many names around the world as Industry 4.0, IIoT, Digital Factory. The essence is not the name, but the available technologies and their possible interconnections.

Naturally, this process has advantages and disadvantage too and now we can hardly see what will happen exactly in the near future. But what we clearly see is the following. The complexity and the capability of these systems stand on incredible level. The knowledge that needs to create, update or operate these kinds of solution is also high. The fact is, the humanity has a big chance with this to do something really good. Probably, this will bring fundamental changes in all areas of our lives. But we can only use this opportunity if we can prepare ourselves in time.

Our goal is to create a multipurpose laboratory in the area of Industry 4.0. This solution will be able to use in the followings:

- The laboratory will serve as an infrastructural basis for useful industrial researches, which in the future can contribute to the development of the Industry 4.0 concept and its newer versions.
- The infrastructure of the laboratory will support the teaching of modern industrial processes. The students can learn about the structure and the interoperation of this modular architecture, i.e. students can learn the functions, working flows and the place of the main units / components / elements / entities of the modern digital industrial area.
- The students can understand the whole system and the relationship between each unit.
- The motivation and innovation level of the students are kept high and give them a chance to develop new capabilities of the system.
- It can become a cooperation and collaboration environment between the university and the industrial partners. The laboratory can demonstrate the possibilities of this new technology in practice. Moreover, this environment makes it possible on the one hand to introduce and on the other hand to develop and test new technologies before industrial deployment.

An important design aspect is to develop the laboratory with modular structure. This property is important in many cases. One of these is that the capabilities of the laboratory can be expanded or modified with the help of minor improvements. On the other hand, we can schedule of the activation time of some functions of the system. This enables this development on a campus with small resource.

4. SYSTEM PLAN

Our system will include all main components of a modern, fully automated industrial solution. This is necessary to reach the multipurpose operational area. Note that we want to model this process from the ordering of a customized product - through the production - to the customer’s service, i.e. the whole supply chain. This activity requires coordinated work of numerous research areas.

There are some dominant areas for example adaptive systems, data mining, machine learning, optimization, protocol technology, and sensor and computer networks.

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Fig. 1 shows the logical structure of the system, where the tasks of each element are the followings:

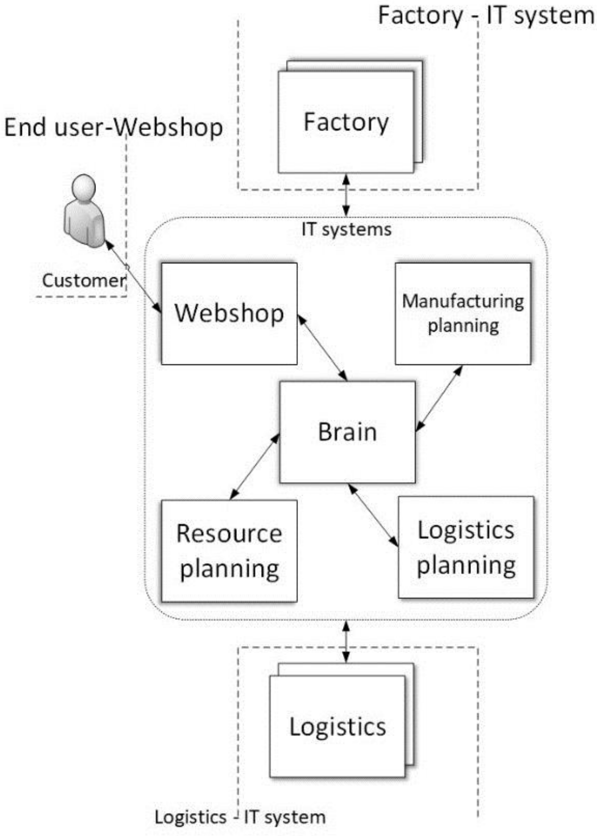

Figure 1. The logical structure of the system

Customer: This entity indicates the manufacturing process. Note that this means the factory will only produce the ordered products.
Brain: This is the central unit and its main functions are the process control and the information management: collection and transmission of information.
Webshop: The customer can manage (buy, modify, get information) his/her order with the help of this unit. This subsystem communicates with the brain unit.
Manufacturing planning: This unit determines the production scheduling and the raw material requirements based on the order.
Logistics planning: This unit determines the scheduling of logistics for the manufacturing process based on the order.
Resource planning: This unit selects the specific factory and logistics partner involved in the manufacturing process based on the availability information and manufacturing parameters.
Logistics: This unit is responsible for transportation, it provides information on its activities.
Factory: The task of this unit is the physical production. It provides information on its activities.
It is important to note that the Webshop, the Brain, the Manufacturing planning, the Logistics planning and the Resource Planning are IT systems / services that work together in the process.

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Because of its complexity, the system will be implemented in several phases. Therefore, the individual functions will be integrated step by step into the system. In the first phase the Factory Subsystem will be realized. The next section describes the architecture of the Factory Subsystem in details.

5. FACTORY SUBSYSTEM

The task of the Factory Subsystem is to start and coordinate the manufacturing processes necessary to fulfill the orders. There are many aspects to consider when planning the manufacturing processes. This becomes more difficult, when we want to expand the manufacturing processes with further processes, taking into account the currently running ones. This requires centralized manufacturing planning that should guide all sub-components.
Fig. 2 shows the logical structure of the Factory Subsystem. The main information is provided by the Enterprise Resource Planning System (ERPS). It is transmitted through an interface that forms a transition between a particular ERPS and the specific control software. The purpose of the interface is to connect different ERPSs and modular control systems.
The Manufacturing Controller (MC) can deliver tasks in the form of instructions from the data contained in the ERPSs (orders, manufacturing scheme, etc.). The MC includes the Manufacturing Logistics Controller, which controls material handling between the factory and the factory-owned warehouse. It also includes the Manufacturing Line Controller (MLC) that controls the robot or machine controllers performing operations during production. The MLC includes a Manufacturing Line Logistics Controller that controls the material delivery between the robots/machines or production lines required for a given production process, and also includes Host Controllers.
A Host Controller contains the control programs of an associated machine or robot. The Host Controllers communicate with the device using an interface, give instructions and receive feedback about the status of the operations. Depending on their type, this information is returned to the Host Controller or the Data Collector Internal Controller. The purpose of the latter is to further analyse and subsequently optimize operations based on the data obtained during operations, both locally and at a high level.

5.1 Factory Information Flow

The MC is responsible for scheduling and assigning existing and ongoing production processes form the newly received order (received from the ERPS) between the MLCs. It is also tasked with giving instructions to the MLC on which Manufacturing Line needs to meet the order in which they are to be delivered, and where to place the existing goods (intermediate or finished product) from the Manufacturing Line (warehouse or to other Manufacturing Line). The MC can schedule further processes from the returned data and return the status of the running processes to the ERPS and indicate the completion of orders.
The task of the Manufacturing Logistics Controller is to define and pass on the instructions for moving materials within the warehouse to the controllers of the logistics tools. Starting from the current inventory of the factory-owned warehouse (which is constantly updated), it can coordinate all material handling processes. A further task is to supply the production line of the associated Factory and to coordinate the supply according to the instructions of the MC. The MLC controls the controllers of the devices that perform operations within the Factory and schedule the associated devices. On the basis of the instructions received from the production control, the instruction sequences are issued to the Host Controllers in the order specified. An instruction contains the product manufacturing sub-scheme that the device must perform and the repeat number of the operation. The Manufacturing Line Logistics Controller receives the instructions that meet the needs of the raw material needed to perform the given Host operation, as well as the material delivery tasks between the Hosts.

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Analecta Technica Szegedinensia
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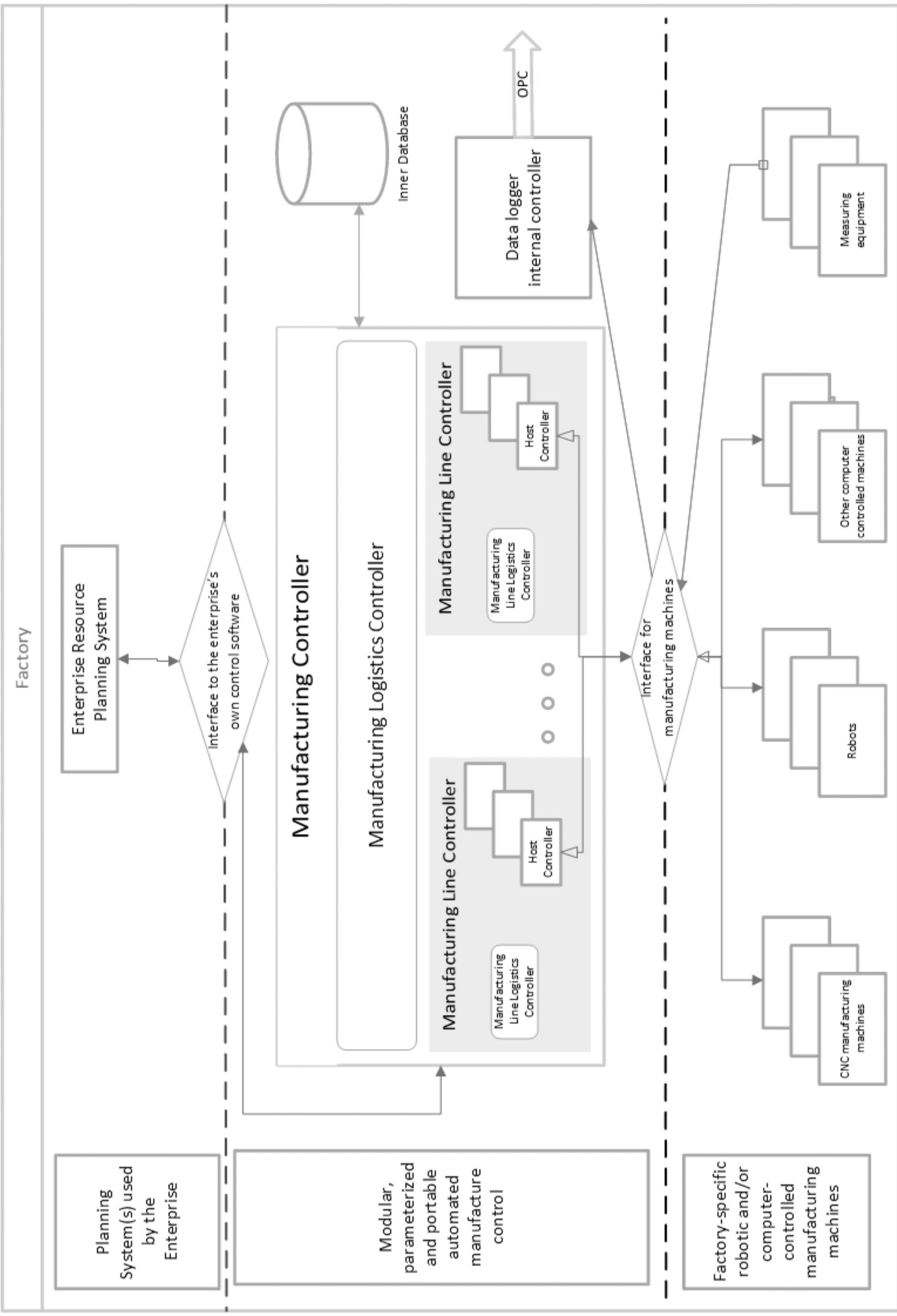

Figure 2. The Factory Subsystem

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6. CONCLUSION

Industry 4.0 strategy includes a number of modern technologies that can be used to digitize production or even the entire supply chain. In University of Pannonia Nagykanizsa Campus an Industry 4.0 based laboratory is currently under construction. The aims of the laboratory are teaching university students, making research in the field of Industry 4.0 and implementing industrial flows in small scale.
The present paper is represented the modular model of the laboratory especially the Factory Subsystem. Currently, the model is being implemented. During the first phase of the realization the Factory Subsystem is developed. The task of this unit is the physical production. The paper presents the logical structure and the information flow of the subsystem.

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LIFE CYCLE ASSESSMENT OF LIQUID INVERTED SUGAR AND HIGH-FRUCTOSE CORN SYRUP

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ABSTRACT

The aim of this study is to compare the environmental impact of liquid inverted sugar (77°Bx) produced with enzymatic hydrolysis of beet sugar and HFCS (75% DM) produced from corn in a wet milling process. Given the different sweetness equivalents of liquid inverted sugar (77°Bx) and HFCS (75% DM), the reference flows were defined as 900 kg of liquid inverted sugar or 1000 kg HFCS. The analysis was performed with the life cycle assessment (LCA) method focusing on the cradle-to-gate stage. The inventory data of liquid inverted sugar processing were supplied by a producer while the LCA of HFCS relies on secondary data (literature) which describes the material and energy flows associated with glucose production. Life cycle inventory of relevant inputs and outputs were available from the Ecoinvent 3.4 database. Environmental impacts were calculated with the ReCiPe 2016 (H) life cycle impact assessment (LCIA) method. LCA results have revealed that inverted liquid sugar has a lower impact in 14 out of the 18 analysed impact categories. Consumption of inverted liquid sugar (>77°Bx) instead of HFCS (75% DM) could lead to significant reduction in GHG emissions (by 38%), fossil energy (by 31%) and water (by 95%) consumption, and reduces the required land area by 67%.

Keywords: high-fructose corn syrup, inverted sugar syrup, life cycle assessment

1. INTRODUCTION

Sucrose obtained from sugar beet or sugar cane has been a part of the human diet for centuries. Furthermore, sucrose found in fruit or honey has been introduced to the human diet for millennia [1, 2]. In the recent decades, varieties of new sweeteners are developed in order to substitute sucrose in the standard food formulation [3]. Despite huge effort, none of these sweeteners was able to comply with numerous standards currently adopted by food industry regarding colour, aroma, texture, fermentation and shelf-life [4]. However, two liquid sweeteners, inverted sugar syrup and high-fructose corn syrup (HFCS), have found a huge market due to similar characteristics to the basic sucrose solutions.

The process of inverted sugar production includes several technological processes. Firstly, sucrose crystals are dissolved at higher temperature forming sugar syrup above 70% of DM. Afterwards, syrup is cooled and specific amount of corresponding enzyme is added. Hydrolysis of sucrose yields glucose and fructose in 1:1 ratio. After syrup filtration, the obtained inverted sugar syrup (above 70% DM) has increased sweetness level compared to sucrose syrup. Sweetness level of 1 kg of completely inverted sugar syrup (70% DM) is equal to 1 kg of sucrose crystals [5].

The production of high-fructose corn syrup involves 4 major processing steps: (a) wet milling of corn to obtain starch, (b) liquefaction - hydrolysis of the starch to obtain glucose, (c) isomerisation -conversion of a portion of the glucose to fructose, and (d) enrichment of the glucose-fructose stream to increase the fructose concentration. Typical composition of high-fructose corn syrup includes 55% of fructose and 41% of glucose with maltodextrin residues up to 4%. Therefore, 1 kg of HFCS (75% DM) corresponds to the sweetness of 1 kg of sucrose crystals [4].

The aim of this study was to compare the environmental impacts of inverted liquid sugar produced from beet sugar and high-fructose corn syrup. The analysis was performed with the life cycle assessment (LCA) method, which takes into account the potential environmental impacts associated with all the stages of the product's life cycle.

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2. MATERIALS AND METHODS

Life cycle assessment was performed according to the principles of attributional LCA [6] and following the cut-off modelling approach as defined by Ecoinvent [7]. The life cycle impact assessment (LCIA) is based on life cycle inventory (LCI) data which includes information on environmental flows (i.e. emissions and resource use) associated with the entire life cycle of a process or product directly linked to the investigated products.

2.1. Functional unit and reference flows

The functional unit was defined as the sweetness equivalent of 1000 kg of sucrose. The reference flow is the amount of the product necessary to deliver the performance described by the functional unit. Given that liquid inverted sugar (77°Bx) and HFCS (75% DM) have a relative sweetness factor of 1.1 and 1, respectively, the reference flow was defined as 900 kg of liquid inverted sugar or 1000 kg HFCS (Table 1). If not explicitly stated otherwise, data in tables and charts refer to 1 functional unit and the respective quantity of reference flow.

Table 1. Description of the analysed products and reference flows

Product name	Description	Functional unit	Reference flow
Liquid inverted sugar	Inverted liquid sugar >77°Bx from beet sugar produced from sugar beet cultivated in Germany.	Sweetness equivalent of 1000 kg of sucrose	900 kg of liquid inverted sugar
High-fructose corn syrup*	HFCS (75% DM) produced from corn in a wet milling process (global average production).		1000 kg of HFCS

** due to unavailability of data referring to the HFCS product system, the HFCS is represented with the impact of glucose syrup (75% DM) made from corn grain (see section Limitation of the study).*

2.2. System boundaries and life cycle inventory data

In this study, system boundary includes only processes associated with the production chain of the analysed products. Distribution, use of liquid inverted sugar and HFCS by food manufacturers or consumers, and disposal are not considered in this LCA as there is substantial variation in the potential use for these products. Furthermore, environmental flows associated with the construction, maintenance and disposal of infrastructure, buildings and equipment in the processing stage was not considered according to their minor contribution proved by previous LCA studies related to food products.

Data on the consumption of materials and energy during beet sugar processing into inverted sugar were collected from the industry (primary data), while the quantity of material and energy flows associated with HFCS processing was estimated based on literature data (secondary data). Life cycle inventory (LCI) of material and energy flows associated with inverted sugar or HFCS processing are available from the Ecoinvent 3.4 database. The Ecoinvent LCI database [8] is considered to be the most comprehensive and reliable LCI database in Europe and includes a comprehensive accounting of emissions emitted and resources consumed in the entire life cycle of many products and processes.

In the inverted liquid sugar processing module, the dataset includes the electricity and heat requirements (from natural gas combusted in average industrial boiler), as well as tap water required for sugar processing and washing of the process equipment (Table 2). Potential impacts associated with the production of enzymes and treatments of waste water generated during the process are also considered.

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Data on chemicals and cleaning agents used in the processing process were not provided by the producer and they are not included in the assessment. Life cycle inventory data of inputs associated with inverted sugar production are available from the Ecoinvent database. The LCI data for beet sugar (primary raw material for liquid inverted sugar production) refer to a typical technology for the production of sugar from sugar beet in the period 1998–2005 in Europe (sweet juice is extracted from sugar beets by diffusion and purified and crystallized to sugar). The original ecoinvent process (beet sugar production | sugar, from sugar beet | Cutoff, U - Copy – RoW, Ecoinvent 3.4.) was slightly modified to include only sugar beet produced in Germany on the input side. The LCI dataset of sugar beet includes all relevant environmental flows (emissions and resource consumption) associated with the provision of seeds, mineral fertilizers, pesticides, all machine operations and corresponding machine infrastructure and sheds, transport activities, as well as the direct field emissions from the application of fertilizers and pesticides and the atmospheric CO2 uptake by the sugar beet. Potential CO2 emissions arising from land transformation are not included in the Ecoinvent LCI of sugar beet.

Table 2. Material and energy flows associated with the processing of beet sugar into liquid inverted sugar and their LCI data

	Units	Amount	LCI data (from the ecoinvent 3.4 database)
INPUTS			
Raw materials			
Beet sugar granulated	kg	720	beet sugar production | sugar, from sugar beet | Cutoff, U - Copy - RoW*
Tap water	m^3	0.3	market for tap water | tap water | Cutoff, U - Europe without CH
Transport			
Transport of beet sugar (Distance: 300 km)	tkm	432	market for transport, freight, lorry, unspecified | transport, freight, lorry, unspecified | Cutoff, U - GLO
Processing			
Electricity	kWh	35.48	market for electricity, medium voltage | electricity, medium voltage | Cutoff, U - SL
Heat from natural gas	MJ	435	heat production, natural gas, at industrial furnace >100kW | heat, district or industrial, natural gas | Cutoff, U – Europe without CH
Tap water for washing	m^3	0.66	market for tap water | tap water | Cutoff, U - Europe without CH
Enzymes	kg	0.18	market for enzymes | enzymes | Cutoff, U - GLO
OUTPUTS			
Liquid inverted sugar >77°Bx	kg	1000	Reference product
Wastewater	m^3	0.66	market for wastewater, average | wastewater, average | Cutoff, U - Europe without CH

**modified ecoinvent process (see above).*

The inventory data of corn grain processing into high-fructose corn syrup was derived from literature [9] referring to glucose production using wet milling. The dataset includes aggregated data on electricity and heat consumption, raw materials, chemicals and water usage, as well as information on emissions to air and effluents (Table 3). The potential environmental impact of the corn grain (primary raw material for glucose production) was modelled based on life cycle inventory dataset from the Ecoinvent 3.4 (market for maize grain | maize grain | Cutoff, U – GLO). The inventory data refer to the average inputs/outputs of global corn production in mid 2000s.

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Table 3. Material and energy flows associated with the processing of corn grain into glucose syrup (75% DM) and their LCI data

	Units	Amount	LCI data (from the ecoinvent 3.4 database)
INPUTS			
Raw materials			
Corn grain	kg	1125	market for maize grain | maize grain | Cutoff, U - GLO
Processing			
Electricity	MJ	700.5	market group for electricity, medium voltage | electricity, medium voltage | Cutoff, U - UCTE
Heat from natural gas	MJ	1635.75	heat production, natural gas, at industrial furnace >100kW | heat, district or industrial, natural gas | Cutoff, U - RoW
Lime (CaO)	kg	0.225	quicklime production, milled, loose | quicklime, milled, loose | Cutoff, S - CA-QC
Sulphuric acid (100%)	kg	0.3375	market for sulfuric acid | sulfuric acid | Cutoff, U - GLO
Sulphur dioxide	kg	2.295	market for sulfur dioxide, liquid | sulfur dioxide, liquid | Cutoff, U - RoW
Urea	g	156	market for urea, as N | urea, as N | Cutoff, U - GLO
Sodium hydroxide (50%)	g	211.5	market for sodium hydroxide, without water, in 50% solution state | sodium hydroxide, without water, in 50% solution state | Cutoff, U - GLO
Sodium chloride	g	48.75	Sodium chloride, powder, at plant, processing - FR
Cyclohexane	g	41.25	market for cyclohexane | cyclohexane | Cutoff, U - GLO
Chlorine	g	9	market for chlorine, liquid | chlorine, liquid | Cutoff, U - GLO
Water	m^3	0.495	market for tap water | tap water | Cutoff, U - RoW
OUTPUTS			
Products and by-products			
Glucose syrup (75% DM)	kg	1000	Reference product
Corn gluten feed	kg	201	By-product
Corn gluten meal	kg	60	By-product
Corn oil	kg	20.25	By-product
Emissions to air			
Particulate (PM10)	g	0.525	Emission to air/unspecified
Emissions to water			
BOD5	g	0.15	Emission to water/unspecified
Chlorides	g	89.1	Emission to water/unspecified
Sulphate	g	0.15	Emission to water/unspecified
Suspended matter	g	0.525	Emission to water/unspecified

As seen from the table, glucose production is a multifunctional process, which apart from the main product, glucose, has three by-products (gluten feed, gluten meal and oil). According to ISO 14040:2006 and the principles of attributional LCA the overall impact of a multifunctional process should be portioned

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between its co-products following an allocation procedure. In this study the overall impacts of the processing process is allocated between its co-products following economic allocation. Based on the economic allocation approach, Setzer [10] estimated that 84% of the overall impacts should be attributed to the main product, i.e. glucose.

2.3. Geographical and temporal relevance of the results

Data on material and energy flows associated with beet sugar processing into inverted liquid sugar was collected from a modern industrial-scale facility and describes average consumption of raw materials and utilities in 2018. When relevant, country-specific data were used to calculate the environmental impacts of products and processes associated with the production of inverted liquid sugar. Otherwise, global or European average data were used from the Ecoinvent database. Data on material and energy flows associated with sugar beet production refer to the typical inputs and yields of sugar beet in Germany in the period 2009–2012. Other inputs are mainly represented with Ecoinvent processes describing the flows associated with average technology in 1995–2005.
Data for corn wet milling came from a detailed production inventory of a modern corn wet mill in the USA, as described by Renouf et al. [9]. Although not explicitly stated by the authors, given the year of the publication it is reasonable to assume that the data refer to a typical technology for corn wet milling in early 2000s in the USA. The corn analysis was based on data from the Ecoinvent 3.4 database describing the average input and output flows associated with corn cultivation in the world in the period of 2004–2006. Other inputs of HFCS processing are modelled with Ecoinvent data which usually describe the average production technology in the period from 1995 to 2005. As far as possible the environmental burdens associated with inputs and outputs of HFCS processing are calculated with global data. This means, that the LCA results refer to the average impact of HFCS on global level. If global average data was not available, than regional or country-specific data were used which is clearly indicated in the name of the Ecoinvent LCI dataset (last letters in the name of the Ecoinvent process; see Tables 2 and 3).

2.4. Life cycle impact assessment (LCIA) method

The environmental impact assessment is performed with the ReCiPe 2016 LCIA method [11]. ReCiPe 2016 is the most recent and harmonized indicator approach available for LCIAs. The potential environmental impacts are analysed and measured within 18 midpoint impact categories. As often encountered in scientific models, the assessment follows the hierarchist cultural perspective.

3. RESULTS AND DISCUSSION

3.1. Life cycle impact assessment results

Table 4 summarizes the results of environmental impact assessment within the ReCiPe 2016 midpoint impact categories. Inverted liquid sugar has a lower impact in 14 out of the 18 analysed impact categories. Consumption of inverted liquid sugar (>77°Bx) instead of HFCS (75% DM) could lead to significant reduction in GHG emissions (by 38%), fossil energy (by 31%) and water (by 95%) consumptions, and reduces the land area (by 67%) required to produce the raw materials. HFCS had lower impacts in 4 impact categories (fine particulate matter formation, human non-carcinogenic toxicity, terrestrial acidification and ecotoxicity).

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Table 4. Life cycle environmental impact of liquid inverted sugar and HFCS

Impact category	Unit	Liquid inverted sugar	High-fructose corn syrup*
Fine particulate matter formation (PM)	kg $PM_{2.5\ eq}$	3.07E+00	1.52E+00
Fossil resource scarcity (FD)	kg oil_{eq}	1.17E+02	1.69E+02
Freshwater ecotoxicity (WE)	kg 1,4-DCB	8.71E+00	1.73E+01
Freshwater eutrophication (WEU)	kg P_{eq}	1.32E-01	3.33E-01
Global warming (GW)	kg CO_{2eq}	4.93E+02	7.90E+02
Human carcinogenic toxicity (HTc)	kg 1,4-DCB	1.23E+01	2.41E+01
Human non-carcinogenic toxicity (HTnc)	kg 1,4-DCB	6.34E+02	2.12E+02
Ionizing radiation (IR)	kBq $Co\text{-}60_{eq}$	2.75E+01	5.53E+01
Land use (LU)	$m^2a\ crop_{eq}$	2.30E+02	7.04E+02
Marine ecotoxicity (ME)	kg 1,4-DCB	1.20E+01	1.95E+01
Marine eutrophication (MEU)	kg N_{eq}	5.94E-01	8.76E-01
Mineral resource scarcity (MD)	kg Cu_{eq}	1.13E+00	2.07E+00
Ozone formation, Human health (Oh)	kg NO_{xeq}	1.62E+00	1.75E+00
Ozone formation, Terrestrial ecosystems (Oe)	kg NO_{xeq}	1.65E+00	1.79E+00
Stratospheric ozone depletion (OD)	kg $CFC11_{eq}$	4.40E-03	5.64E-03
Terrestrial acidification (TA)	kg SO_{2eq}	2.08E+01	5.40E+00
Terrestrial ecotoxicity (TE)	kg 1,4-DCB	1.54E+03	1.21E+03
Water consumption (WD)	m^3	1.17E+01	2.37E+02

The following chart (Fig. 1) shows the relative results within the analysed midpoint impact categories. For each indicator, the product with the higher environmental impact is set to 100% and the results of the other product are displayed in relation to this result.

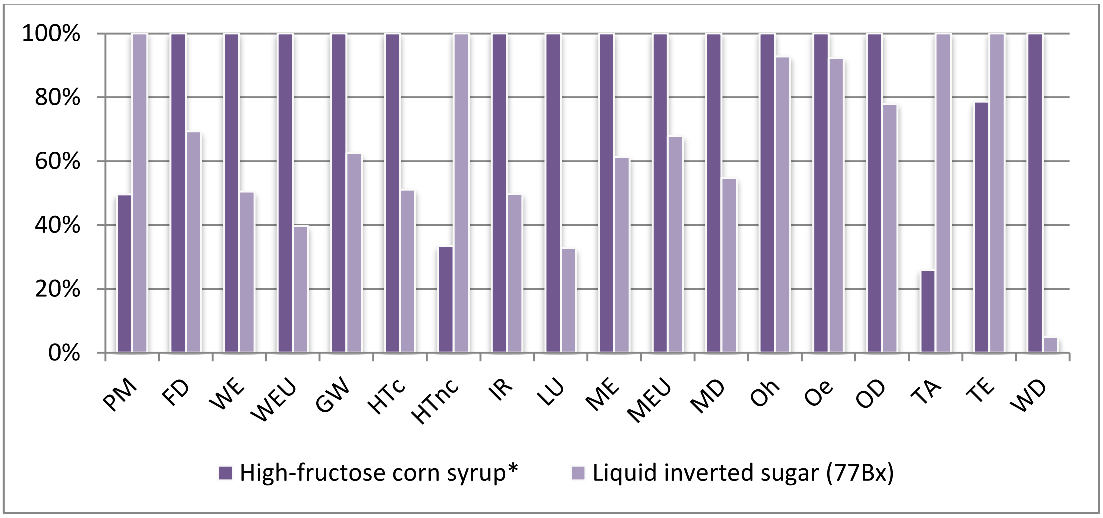

Figure 1. Relative difference between LCIA results for liquid inverted sugar and HCFS (the product with the higher impact category result is set to 100%)

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3.2. Contribution of individual processes to impact category results

Fig. 2 shows the contribution of processes associated with liquid inverted sugar processing to the overall results within the selected life cycle impact category. The figure shows that the overall environmental impact of inverted liquid sugar is dominated by beet sugar production. The beet sugar processing into inverted liquid sugar has relatively minor influence on overall results (in general less than 20%) except in global warming, fossil energy depletion, terrestrial ecotoxicity and human toxicity impact categories. In the later four impact categories the processing related impacts are dominated by impacts associated with transport activities. The relatively high share of transport related impacts in total environmental impact can be explained with large transport distances (300 km in one direction) and the chosen transport mode (road transport) which is characterized by high environmental impact per tkm. Nevertheless, the highest impacts appear in the background system (provision of raw materials) which consists of processes on which the liquid inverted sugar producer has no, or very limited, influence.

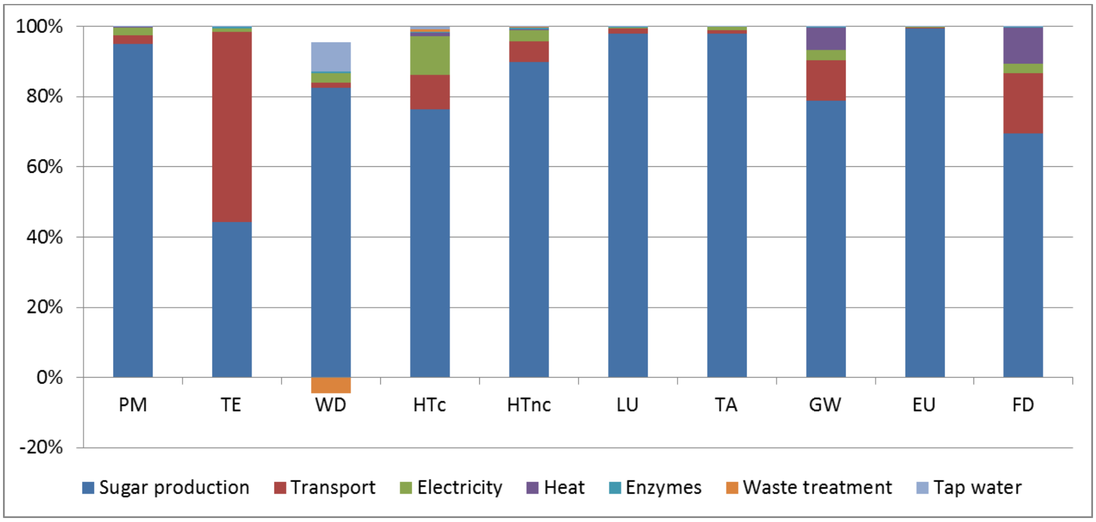

Figure 2. Contribution of individual processes associated with liquid inverted sugar production to impact category results

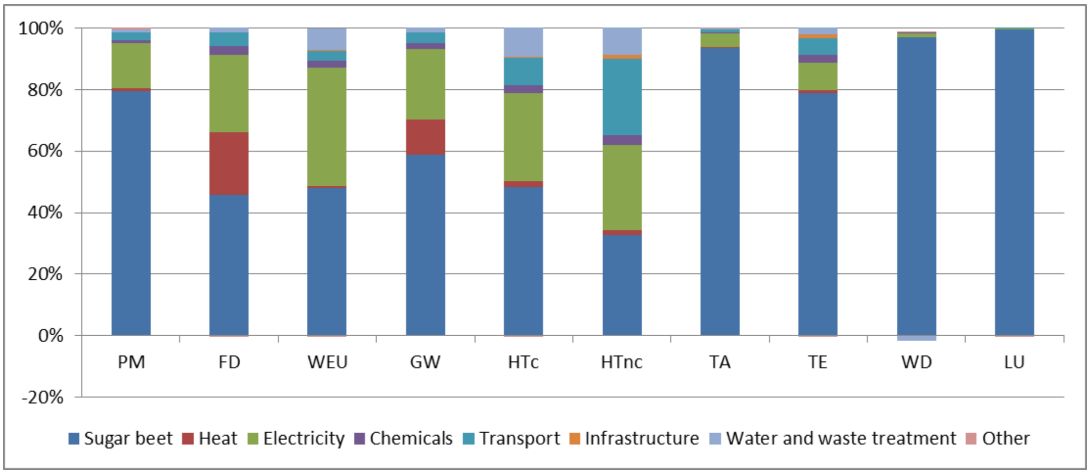

Figure 3. Contribution of processes and flows to the environmental impact of sugar produced from sugar beet

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The figures bellow show the results of the contribution analysis of the two most important upstream processes (in terms of their contribution to the overall results), that is beet sugar production and sugar beet production. As anticipated, the overall environmental impact of sugar is dominated by impacts associated with sugar beet cultivation. Impacts associated with the production of fertilizers, field emissions (from the application of fertilizers and pesticides) along with machinery (diesel fuel) are the main impacts related to sugar beet production.

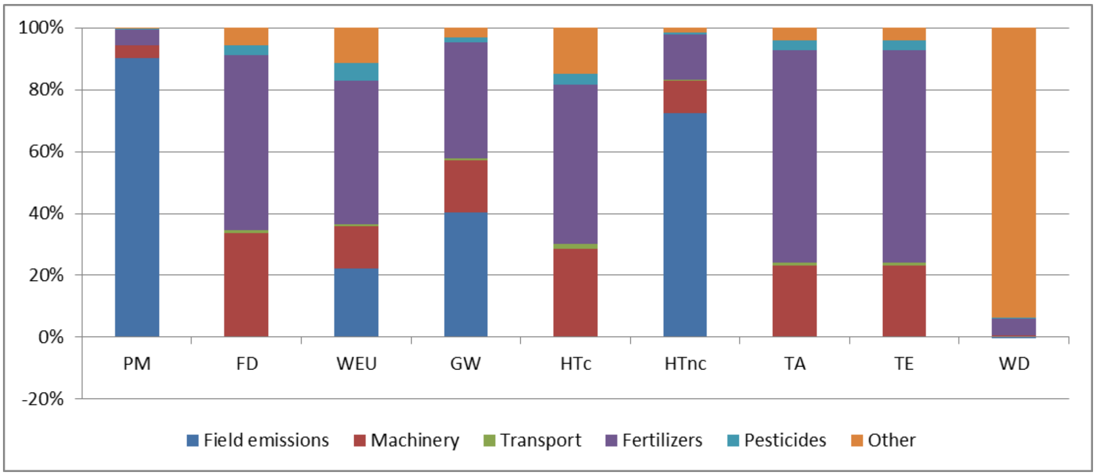

Figure 4. Contribution of processes and flows to the environmental impact of beet sugar produced in Germany

Contribution of individual process to the overall environmental impact of HFCS within the selected impact categories is depicted in Fig. 5. Environmental flows (emissions and resource use) associated with corn production cause most of the impacts within the selected impact categories.
The process of corn processing into HFCS has relatively minor influence on overall results within most of the impact categories. Exceptions are the global warming, fossil energy depletion, freshwater eutrophication and human toxicity impact categories in which heat and electricity consumption during the processing stage have significant contribution to the overall impacts.

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Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

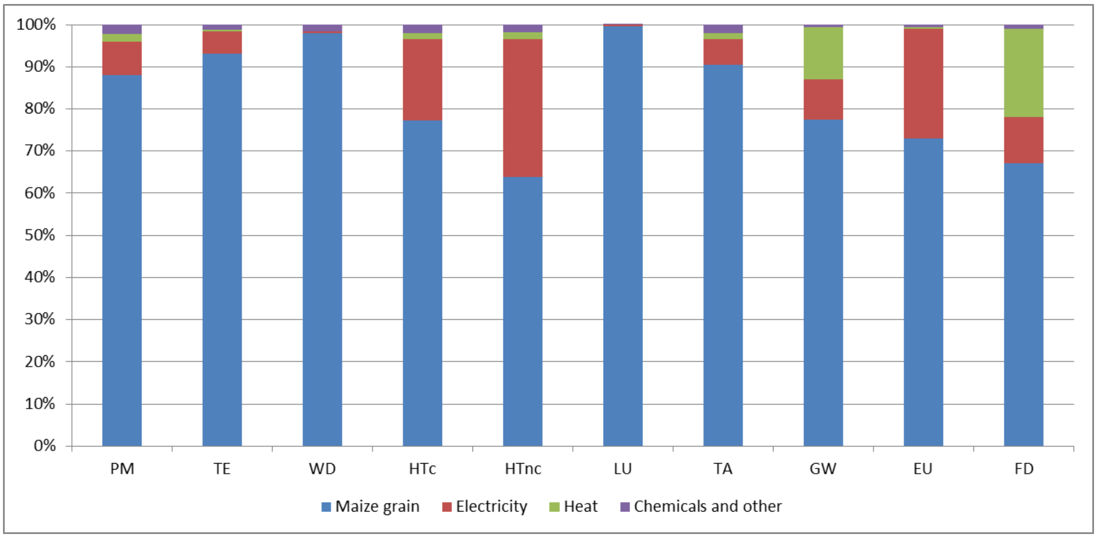

Figure 5. Contribution of individual processes associated with HCFS production to impact category results

The global corn production is dominated by the USA which is responsible for around 38% of the corn produced globally. The figure bellow shows the contribution of processes to the overall environmental impact of corn production in USA („maize grain production | maize grain | Cutoff, U – US"; Ecoinvent 3.4). Field emissions associated with the application of fertilizers and pesticides have a dominant impact in most of the impact categories, however flows associated with drying and production of fertilizers have also significant share in some impact categories. It is interesting to see, that corn production has a positive impact on human toxicity (negative value on the charts). This means that corn removes more heavy metals from the soil (uptake) than it is incorporated into the soil via fertilizers and pesticides.

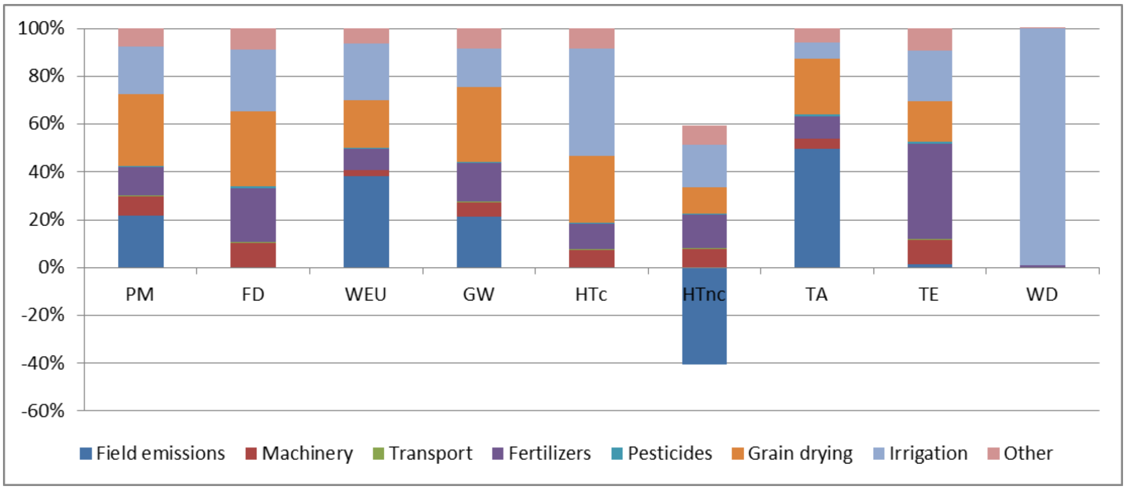

Fig. 6. Contribution of processes and flows to the life cycle environmental impact of the corn produced in USA

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3.3. Limitations of the study

Modelling of inverted liquid sugar relies on primary data supplied by a producer and reliable and comprehensive LCI data (Ecoinvent 3.4 database). Some process inputs (see system boundaries) were not accounted for, but given their relatively small share in the total mass flow, it is not likely that their inclusion would significantly change the results.

The ecoinvent process used to calculated the environmental impact of enzymes refer to enzymes derived from potato starch unlike the one used by the data provider. However, given the small impact of enzymes on overall results (<0.5%), this simplification will not significantly change the results or conclusions.

Modelling of the HFCS product system relies on secondary data from literature sources. Although published in peer-reviewed scientific journal the authors did not provide information on data source, thus it was not possible to check and verify the reliability of the original data source. Furthermore, the data refer to the production of glucose from corn grain. Glucose is the intermediate product of the HFCS production (lacking only the final step of glucose isomerization) but it is not per se the product with the lower environmental impact due to different sweetness level of glucose and HFCS.

The production process described by Renouf et al. [9] refer to sugar production which is intended for fermentation, not for human consumption. In this regard our results likely underestimate the energy requirements for HFCS production. In this study we assigned 16% of the overall impacts to by-products based on economic allocation. Others have assigned larger co-product credits to corn glucose than in this study by undertaking a system expansion to include the potential benefits from avoided production of other processes displaced by corn meal and oil. However, the system expansion approach is not commonly used in the attributional LCA approach, and it is more suitable for consequential LCAs.

3.4. Comparison of the results with other studies

Even after an extensive literature review we were not able to find any LCA study of liquid inverted sugars. Several reports on the life cycle environmental impacts of glucose or HFCS are publicly available and their main findings are listed in the table below (Table 5).

As it can be seen from the table, previous researches have in general focused on intermediate products along the HFCS processing chain and not on HFCS itself. These reports considered only a few environmental aspects (usually only the global warming impact) and provide a very limited description of the analysed processing technology and data source. Despite the severe limitations of the previous LCA studies of HFCS it seems that our results, at least in terms of global warming impact of HFCS (790 kg CO2eq/1000 kg HFCS 75% DM, i.e. 1053 kg CO2eq/1000 kg HFCS 100% DM), are in good agreement with other LCAs of glucose and fructose syrups.

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Table 5. Overview of LCA results of glucose and fructose syrups

Product	Reference flow	LCIA results	Comment	Source
Liquid glucose (including glucose and fructose syrups)	1000 kg of final product (100% DM)	949 kg CO_{2eq} for global warming; 40 m^3 water depletion; 1414 m^2a agricultural land occupation	No details on the processing step at all (no reference to the LCI data or description of the production process or data source).	An et al., 2012. [12]
Isoglucose from US corn	1000 kg isoglucose	1100 kg CO_{2eq} for global warming	Wet milling process in the USA (using economic allocation 84% of emissions to glucose). No details on data source or the amount of flows associated with processing.	Citation in Klenk et al., 2012. [13]
Isoglucose from US corn	1000 kg isoglucose	640 kg CO_{2eq} for global warming	Dry milling process in the USA. No details on data source or the amount of flows associated with processing.	Citation in Klenk et al., 2012. [13]
High fructose corn syrup	1000 kg of HFCS	1000 kg CO_{2eq} for global warming	Based on the study of Renouf et al. (2008).	Kendalla et al., 2010. [14]
Dextrose from corn	1000 kg of glucose (100% DM)	ca. 6000 MJ energy input; 1000 kg CO_{2eq} for global warming; 8.5 kg SO_{4eq} for acidification; 2.8 kg PO_{4eq} for eutrophication potential.	A detailed description of the LCI inventory. Inventory data are derived from non-specified secondary sources.	Renouf et al., 2008. [9]

4. CONCLUSIONS

The comparative cradle-to-gate assessment of inverted liquid sugar and HFCS has revealed that the later has higher impact (i.e. causes more damage) in 14 out of the 18 analysed impact categories. Inverted liquid sugar has lower carbon and water footprint (by 38% and 95%, respectively) and its production requires less fossil energy (by 31%) and agricultural land (by 67%). The processing stage has relatively low contribution to the overall impact of inverted sugars and HFCS (in general less than 20% in most of the impact categories); therefore, further improvements in the process energy efficiency would have just minor impact on the overall results. Most of the life cycle impacts are attributable to the raw material production (i.e. beet sugar and corn grain) on which the inverted liquid sugar or HFCS producer has no, or very limited, influence.

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MECHANICAL AND ENERGY EXAMINATION OF DIFFERENT AGRIPELLETS

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ABSTRACT

As an indirect consequence of climate change, the reduction of carbon dioxide emissions, the energy utilization of agricultural by-products will be increasingly emphasized in the future. Hungary has a large potential of agricultural residues of which is a big part could be used for energy purposes. Common feature of this by-products is that thay are originally difficult to handle and they have a small bulk density. Pellet production is one possible way to utilization, however the high ash content and low ash melting point cause problems in pellet burner equipments. Mixtures of different plant residues (wheat straw, rape seed stem, sunflower husk) and agripellets have different energetic and mechanical properties. Besides high ash content and low ash softening temperature, mechanical properties can also significantly affect the quality of pellets as well as the efficiency of firing. There were also significant differences in diameter, length, bulk density and mechanical durability of pellets.

Keywords: agri-pellet, rape seed stem, wheat straw, sunflower husk

1. INTRODUCTION

Since the Industrial Revolution, CO_2 levels have risen from 180 ppm to over 400 ppm and other greenhouse gases such as methane and N_2O are rising, which, according to several researchers has triggered an irreversible warming process [1]. In addition to environmental reasons, energy supply based on fossil resources in the European Union and in Hungary also leads to strong import dependency. Due to its soil and climatological features, Hungary has a large potential of biomass for energy purposes. In order to increase the share of renewable energies, the energetic utilization of biomass is a possible alternative. Forestry, wood industrial and agricultural by-products are available in large quantities. The common feature of the raw materials is that they are difficult to handle in their original condition, their firing is problematic and they have low bulk density.

The pellet is a high-pressure energy compact, cylindrical granulate. It is characterized by high density (600-850 kg / m3) and compactness [2]. Diameter of pellets is usually between 5-10 mm, length 10-35 mm [Burján, 2010]. A common feature of agricultural by-products is that they have low bulk density, so transportation is not economical and firing is also problematic. The production of agripellet allows us to produce fuel that can be utilized in an automated way with good energy efficiency based on our previous studies[3].

The pellet sector has started to develop rapidly in Europe, and in recent years the number of wood pellet factories has been doubled, mainly using wood shavings as a by-product of wood industry. Due to increasing the share of renewable energies and the limited availability of wood-based stocks pellets are produced from agricultural by-products, mainly from straw and stems will play a greater role in the future. These herbaceous plants residues are re-produced on arable land every year and have significant potential for energy utilization. The use of agripellets in the European Union is also steadily increasing, but it is still dwarfing compared to a higher quality wood pellet.

There are several reasons for the slower spread of agri-pellets. The high ash content of the herbaceous plants and the low ash melting temperatures often cause problems in the burning systems. Melting and slagging temperatures of wood-based fuels are generally above 1000 °C degrees, around 1100-1200 °C degrees, in contrast, the herbaceous plants are melt around 600-850 °C [4,5,6,7,]. In addition, the energy characteristics and the heating value are significantly lower than in wood pellets[8].
Of the chemical components, the presence of lignin, pentosans, and protein greatly influences the properties of the pellets. The presence of lignin changes the bonding properties. It melts at a relatively low temperature of 140 °C, and later holds together the particles after compaction [9]. Protein content also plays an important role in the formation of pellets. The residence time, temperature and high pressure cause partial denaturation of proteins [10]. Caroll and Finnan studied chemical and physical properties of pellets by woody and herbaceous material, rapeseed straw, wheat straw, barley straw and energy crops, willow and mischantus reeds. According to their results, the upper heating value of rapeseed was 18.2 MJ / kg, the ash content was 5.3%. Different pellets were produced at 6 mm press hole with a small pelletizer (max capacity 150 kg / h). Among the investigated materials, the mechanical durabilitiy of Mischantus reed was 95,2% the rapeseed stem pellet was 95.8%, wheat and barley straw pellets were better 96.3% and 96.8%[11].

2. MATERIALS AND METHODS

Pellets produced under operational and laboratory conditions were also examined. Among the energy properties, the calorific value, the moisture content and ash content were determined. In the course of the experiments, a mixture of pellets of rape seed stem, wheat straw and sunflower husk were produced by experimental (Kahl type) pelletizing equipment. The rape stem utilization is justified by the fact that in recent years its production area has increased significantly in Hungary, in the year 2018 it was grown on more than 300 thousand hectares [12]. The amount of rape stem per hectare can be twice the weight of the seed. The largest area in the country is occupied by cereals, wheat and barley. Significant amounts of by-products, straw and stem are produced annually of witch a significant part could be use for energy purposes.
In the course of the tests, three types of agripellets were produced, a pellet with a 6 mm diamter press hole from a pure rapeseed stem, an 8 mm diameter hole with rape stem and with the addition of 50 % wheat straw. Pellets made from sunflower husk were produced under operational conditions in a pellet plant. Among mechanical properties, the diameter and length of the pellets, the fine particle size and the mechanical durability were examined.
Determining the calorific value from an energy point of view is one of the most important issues. The higher heating value was determined by calorimetric measurements. The lower heating value can be calculated by using the following formula:

$$Lower\ heating\ value(\mathrm{LHV}) = \frac{HHV-\left(\frac{2447\cdot(U+9\cdot H)}{100}\right)}{1+\frac{U}{100}}\left[\frac{kJ}{kg}\right] \tag{1}$$

HHV – Higher heating value of the test substance (measured value)
U - gross moisture content of the test substance [m /m%]
H - Hydrogen content of the test substance [~ 6 m /m%]

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Figure 1. IKA-C 2000 type Calorimeter

Ash content is an important for energy aspect, and it is also important for firing equipment design. The ash content of wood pellet is low, usually below 0.5 %, while agri pellets from herbaceous plants have a higher ash content of about 3 to 10 %. The ash content was determined by muffle furnace test. From a firing point of view, moisture content is one of the most important properties, since it is closely related to the heating value [13]. Determining the moisture content is also important because of the pelletization, if the wet content is too high or too low, the pellet will breaking and fall apart.

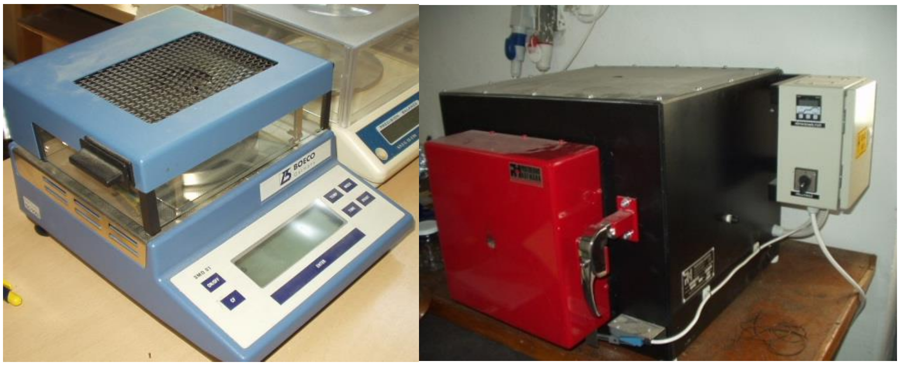

Figure 2. Moisture content analyzer and muffle furnace

The determination of the fine particle is an important aspect of the combustion technology of pellets. If the fine proportion is too high, problems may arise during combustion, the flue gas composition changes, efficiency decreases. A perforated sieve made in accordance with ISO 3310-2 should be used - according to MSZ EN 15210-1 - to sieved the pellet to determine the fine particle size (the so-called "crumb").

Figure 3. Determining the fine proportion by sieving

From a sample of about 1.2 kg, the sieve is used to manually remove the crumb by a few circular movements, which can be calculated with the following formula:

$$F = 1 - \frac{m_A}{m_E} \quad [\%] \tag{2}$$

where
F – Fine fraction proportion [%]
m_E - sample weight before sieving [g]
m_A - sample weight after sieving [g]

2.1 Mechanical resistance and durability of pellets (DU)

The mechanical durability of pellets is described in MSZ EB 15210-2 standard. The measurement was carried out by the self-developed equipment of the University of Sopron, Institute of Mechanical Engineering and Mechatronics in accordance with the standard. The 500 ± 10 g pellet, which had to be sieved and weighed on a 3.15 mm perforated sieve, was loaded into the pellet testing apparatus (shown in Figure 4.) and then rotated for 10 minutes at 50 ± 2 round/min the pattern. After the mechanical rotation, the pellet is filled into the sieve and weighted again.

Figure 4. Measurement of mechanical durability

Determine the mechanical durability of the pellet using the two samples measured and the following formula:

$$D_U = \frac{m'_A}{m'_E} \quad [\%] \tag{3}$$

where:

Du – Mechanical durability (%)
m'_E - Weight of pellets above 3.15 mm before mechanical treatment (after sieving) [g]
m'_A - Weight of pellets above 3.15 mm after mechanical treatment (after sieving) [g]

2.2 Pellet length and diameter

In the case of pellets, it is an important requirement, based on the ENplus recommendation using EN 14961-2, to have an average length of between 3.15 and 40 mm. The length of the pellets can be influenced by many factors. The particle size, moisture, and above all the material composition. The tests should be carried out on all pellets in a sample of 80 to 100 grams using a simple caliper. Measuring uncertainty is of paramount importance in measuring length, since subjective determination of the center of measurement of length and other random measurement errors can result in a significant absolute error. According to the research of wood pellets published by Németh in 2014, the calculated total error was ± 1.66 mm (including the 0.02 mm error of the instrument)[14]. Its significance lies in the fact that in case of measured pellet types it is not practical to simply accept the results obtained as an average, but it is necessary to give the mean length values together with the measurement error [14].
Bulk (Volumetric) density ("BD")
Bulk density is an important parameter in the transport of pellets. According to MSZ EN 15103, an analytical balance and a standard 5 liter tank are required for testing.

Figure 5. Measurement of bulk density

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Based on the following formula, this parameter can be calculated by taking the measured values into account:

$$BD_{ar} = \frac{(m_2 - m_1)}{V} \left[\frac{kg}{m^3}\right] \tag{4}$$

where:
BD_{ar} - volume density of the sample taken (moisture content)
m_1 - tank weight [kg]
m_2 - total weight of the sample and tank (“saturated” tank weight) [kg]
V - tank volume [m^3]

3. RESULTS

There was a significant difference in the mechanical properties of the pellets due to the different diameters and the mixture of different materials. The measurements were repeated three times, the average of the results being shown in Table 1.

Table 1. Mechanical properties of sunflower husk, rape seed stem and wheat straw blend pellets

	Fine fraction proportion %	**Bulk density kg/m3**	**Mechanical durability %**	**Mean medium length mm**	**Mean diameter mm**
Rapeseed stem pellet 6 mm	0,3	638	97,3	17,1	6,4
Rapeseed stem pellet 8 mm	0,6	610	96,4	15,4	8,5
Rapeseed stem- wheat straw(50%) 8 mm	0,3	612	98,1	16,2	8,4
Sunflower husk pellet 6 mm	0,5	560	94,6	15,8	6,4

The average medium length of the 8mm pellet was significantly lower than the 6mm rapeseed stem pellet. The fine proportion of pure rapeseed stem pellets was higher than that of the blend pellets. Mechanical durability was also better for blend pellets, which is important from a firing point of view. If the proportion of small, fragmented fractions is too high, the efficiency may decrease. According to the quality requirements, the rapeseed straw pellets can be classified into EN-B category based on mechanical properties, while the mix pellet can be classified into EN A2 category. However, the ash content for each pellet exceeded the 3% allowed for the agripellets, which is only the EN-B category. Sunflower pellet has the highest calorific value among the samples tested. The outstanding calorific value is caused by residual oil in the husk.

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Table 2. Energy properties of sunflower husk, rape seed and wheat straw pellets

	Wet content %	Heating Value MJ/kg	Ash content %
Rape seed stem pellet	9,4	16,3	5,2
Rapeseed stem- wheat straw (50%)	8,7	15,9	8,3
Sunflower husk pellet	8,9	17,9	3,1

4.CONCLUSIONS

There were significant differences in the mechanical properties of the examined pellets. The different press hole diameters and the different material composition also affected the results. Properties of pellets made from rapeseed stems was less favorable than wheat straw blends. The mechanical properties can significantly affect the firing parameters. In the future, flue gas analysis tests could be carried out to get information on efficiency and other firing parameters.

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EFFECTS OF EXTERNAL DISTURBANCES ON THE PERFORMANCE OF AN AXIAL COOLING FAN

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ABSTRACT

In this study flow around an axial flow fan is investigated by the means of CFD computations using the commercial software package, ANSYS Fluent. The rotation speed of the impeller was set to the constant value of n = 2500min-1. The results obtained from the computation are validated against those from measurements; good agreements can be seen. The effects of two different external disturbances are analysed. First, the fan was place into a uniform stream where the free stream velocity is varied between U = 0 and 100 km/h. After that, a computation is carried out for U = 0 km/h where the half of the suction side of the fan was covered by a flat plate. The results showed that the fluid pressure and the aerodynamic force increases with the free stream velocity. Asymmetric pressure and fluid force distribution was identified when suction side of the fan was partially covered.

Keywords: aerodynamic forces, CFD, covering, fan, free stream velocity

1. INTRODUCTION

Nowadays, modelling of fluid flow in an axial flow fan is a common engineering problem. Using the available commercial software packages this problem can be handled.
Two types of noise are emitted from the cooling fan of an automotive engine: tonal and broadband noises. Many researchers have studied how these kinds of noises can be reduced [1, 2]. Park and Lee [1] investigated the source of broadband noise from a shrouded automotive cooling fan using a hybrid approach. The calculation of the noise generated by the fan required a large computational domain. A hybrid mesh was created on the geometry consisting 5.2 million cells. The turbulent flow around the fan was modelled by the k-ω SST turbulence model and the noise was predicted using the generalized acoustic analogy of Ffowcs Williams and Hawkings [3]. In order to reduce the computational cost, for first, Park and Lee [1] carried out steady state computations. Once the residual errors decreased to the convergence criteria, they continued the computations considering unsteady flow field.
The computational time is greatly increased by modelling the entire fan unit. If the geometrical properties of the impeller blades are the same and the spacing is constant, it is possible to examine the flow around only one blade section using periodic boundary conditions. Pogorelov et al. [4] used Large Eddy Simulation (LES) and investigated the effect of the gap between the rotating and the stationary parts of the fan. They found that by reducing the tip-gap width, the amplitude of tip-gap vortex wandering is decreasing and the frequencies of the dominant modes are increasing. They also found that tip-gap vortex shedding play an important role in the noise generation.
Lallier-Daniels et al. [2] analysed the acoustic properties of a cooling fan module using Lattice-Boltzmann Method (LBM). The results from the CFD computations were compared with their measurement results obtained using a microphone placed in front of the fan. The comparison between the numerical and experimental results showed good agreements.
Ambdekar et al. [5] investigated the flow structures in a cooling fan using the commercial software package ANSYS Fluent. They investigated the velocity and pressure fields inside the fan, the uniformity of flow in the outlet, the separation zones, the possible locations of cavitation and the noise load.

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In this paper three-dimensional flow around an axial cooling fan is investigated using the commercial CFD software package, ANSYS Fluent. The results obtained using the currently applied computational approach is validated against measurement results. After the code validation, simulations are carried out using two types of external disturbances. First, the axial fan is placed into a uniform flow. The effects of free stream velocity ranging between U = 0 and 100 km/h are analysed. After that, with zero free stream velocity U = 0 km/h, the half of the suction side of the fan is covered using a flat plate. Three components of fluid force acting on the blade sections are computed and the pressure distribution on the impeller is shown.

2. COMPUTATIONAL SETUP

In this study three-dimensional, incompressible, Newtonian fluid flow around an axial flow fan is modelled using the commercial software package ANSYS Fluent. Three components of the Navier-Stokes equations and continuity equation are solved. Based on the studies of [5–7], Reynolds stresses are approximated using the realizable k-ε turbulence model. The rotating motion of the impeller is modelled using the sliding mesh method.

A schematic diagram of the computational domain is shown in Fig. 1. The axial fan is placed into a channel which height, downstream and upstream length and width are set to 0.804 m, 2.349 m, 2.378 m and 1.2 m, respectively. A cover (flat plate) is placed on the suction side of the fan which is divided into 13 sub-surfaces. These wall surfaces can be 'activated' or 'inactivated' during computations. In case a sub-surface is activated, no-slip boundary conditions are satisfied on it, otherwise, air can flow through it.

Dirichlet-types of boundary conditions are applied for the three velocity components on the solid surfaces of the fan and in the inlet cross-section. In the inlet uniform stream is prescribed by giving the free stream velocity U. Neumann-types of boundary conditions are used for fluid pressure and for the velocity components in the outlet cross-section.

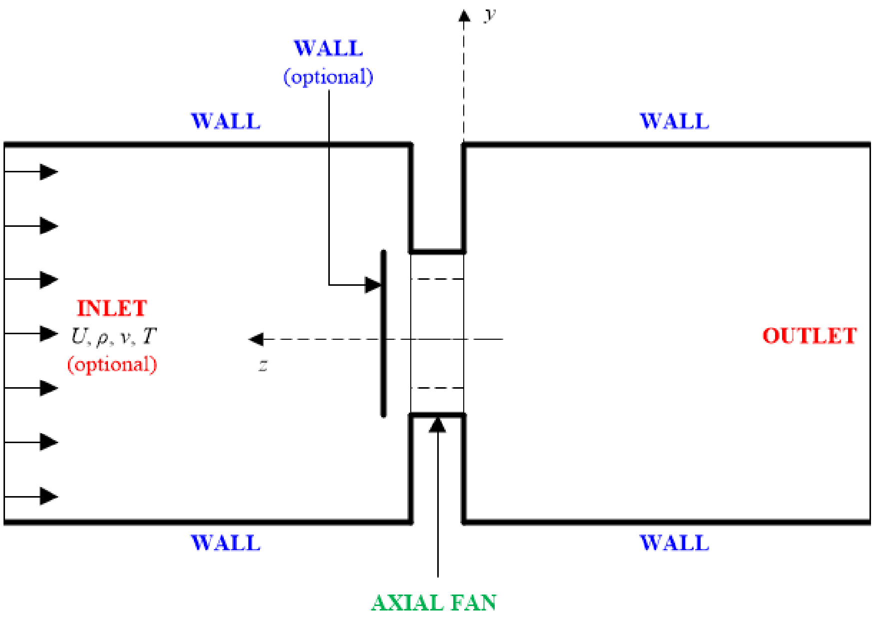

Figure 1. The schematic diagram of the computational domain

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Figure 2 shows the numerical grid created on the computational domain. It can be seen that the radial cells are logarithmically spaced, providing a fine grid scale near the solid bodies and relatively coarse grid in the far field. The mesh contains approximately 58 million cells.

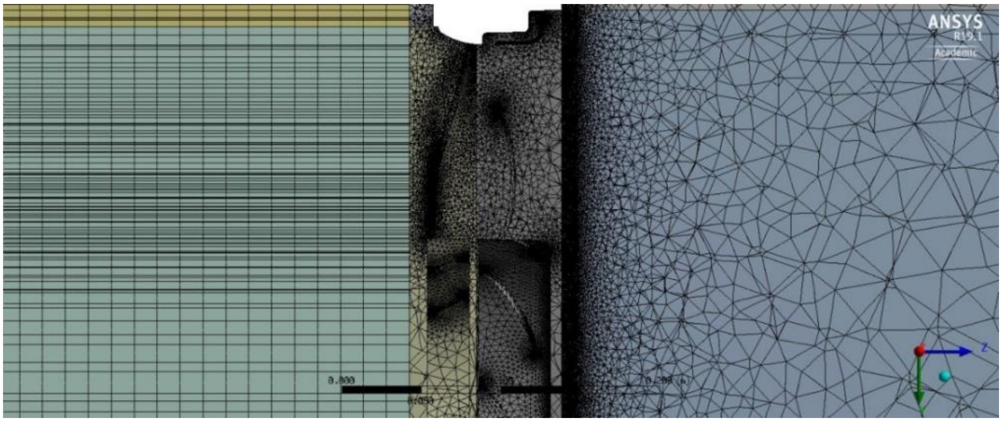

Figure 2. Mesh

The governing equations with the boundary conditions are solved using finite volume method. Second order upwind scheme was used to discretize the convective terms in the momentum equations. The Semi-Implicit Method for the Pressure Linked Equations (SIMPLE) scheme is applied for the pressure-velocity coupling.

3. CODE VALIDATION

Firstly, the results from the applied computational method are validated against experimental results. For this investigation the flat plate on the suction side of the axial fan is inactivate and the rotation speed of the impeller and the free stream velocity in the inlet cross-section are set to n = 2500 min-1 and U = 0 km/h, respectively. For this rotation speed value the revolution time is under t_{rev} = 60/2500 = 0.024 s. The impeller is turned by 5° in each time step, that is, the time step was chosen to be Δt = 0.0003s.

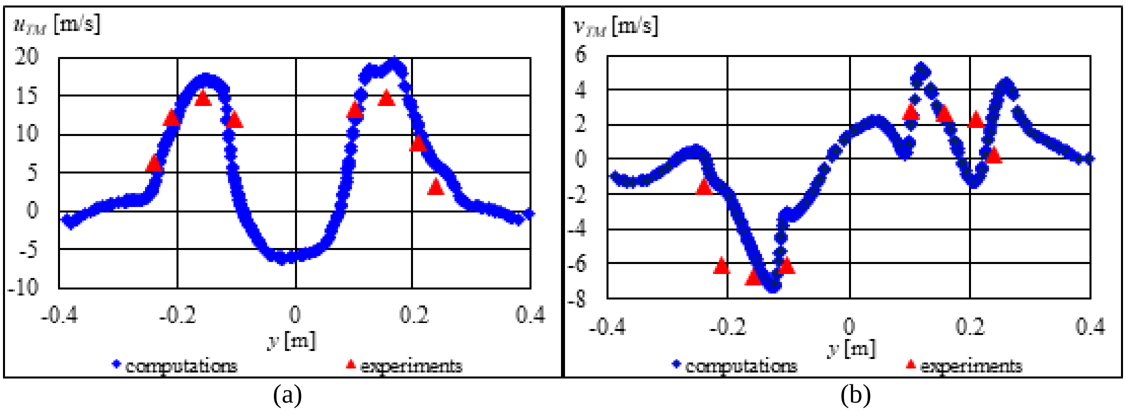

Figure 3. Comparison between computational and experimental results using the time mean values of u and v velocity components

Experiments are carried out using Constant Temperature Anemometry (CTA) technique. During the measurements the time series of u and v velocity components are measured at eight distinct points along the y axis (shown in Fig. 1), $\Delta z = 0.1$ m away from the fan on the pressure side. The sampling frequency was set to 1 kHz and 30s measurement time (in each point) was considered.
In Fig. 3a and b the comparison between the computational and experimental results using the time-mean values of u and v velocity components (u_{TM} and v_{TM}) are shown. It can be seen that the agreements are relatively good, the data sets are in an acceptable tolerance.

4. RESULTS AND DISCUSSION

After the code validation, computations are carried out to investigate the effects of the free stream velocity and the covering surface placed on the suction side of the fan. The rotation speed was set to n = 2500 min-1 similar to that in the validation procedure. During the investigations the three components (in Cartesian coordinate system) of the aerodynamic force (F_x, F_y and F_z) acting on the fan blades and the pressure distribution on the impeller are investigated.

4.1. The effects of free stream velocity

In Fig. 4a and b F_x and F_y aerodynamic force components acting on the blade sections are shown for the free stream velocity values of U = 0, 35, 70 and 100 km/h. The identification numbers of each blade are shown in Fig. 5. It can be seen that these force components can be either greater than and lower than zero for an arbitrary free stream velocity value. In case F_x or F_y is negative the force acts opposite to the rotating direction of the impeller, while for $F_x > 0$ or $F_y > 0$ the force acts in the direction of rotation. It can also be seen that F_x and F_y for U = 70 and 100 km/h increase and decrease at the same locations, so that the force components for these two U values are 'in-phase'. In contrast, the calculated F_x and F_y values for U = 35 km/h are out of phase with those at U = 70 and 100 km/h.
In Fig. 4c the aerodynamic force component in the axial direction F_z is shown for the aforementioned free stream velocity values. It can be seen that F_z is significantly greater than F_x and F_y which is expected. Surprisingly, F_z can also be positive and negative. For positive and negative values the force acts in and opposite to the direction of the main stream, respectively.
In Fig. 5 the pressure distribution on the impeller of the fan is shown for the investigated free stream velocity values. It can be seen that the pressure increases with U which can cause increasing aerodynamic forces on the blades. This statement is true for U > 35 km/h, while at the range of U < 35 km/h additional investigations are required. It is also shown in the figure that the pressure on the pressure side of the fan is always lower than that on the suction side which is also expected.

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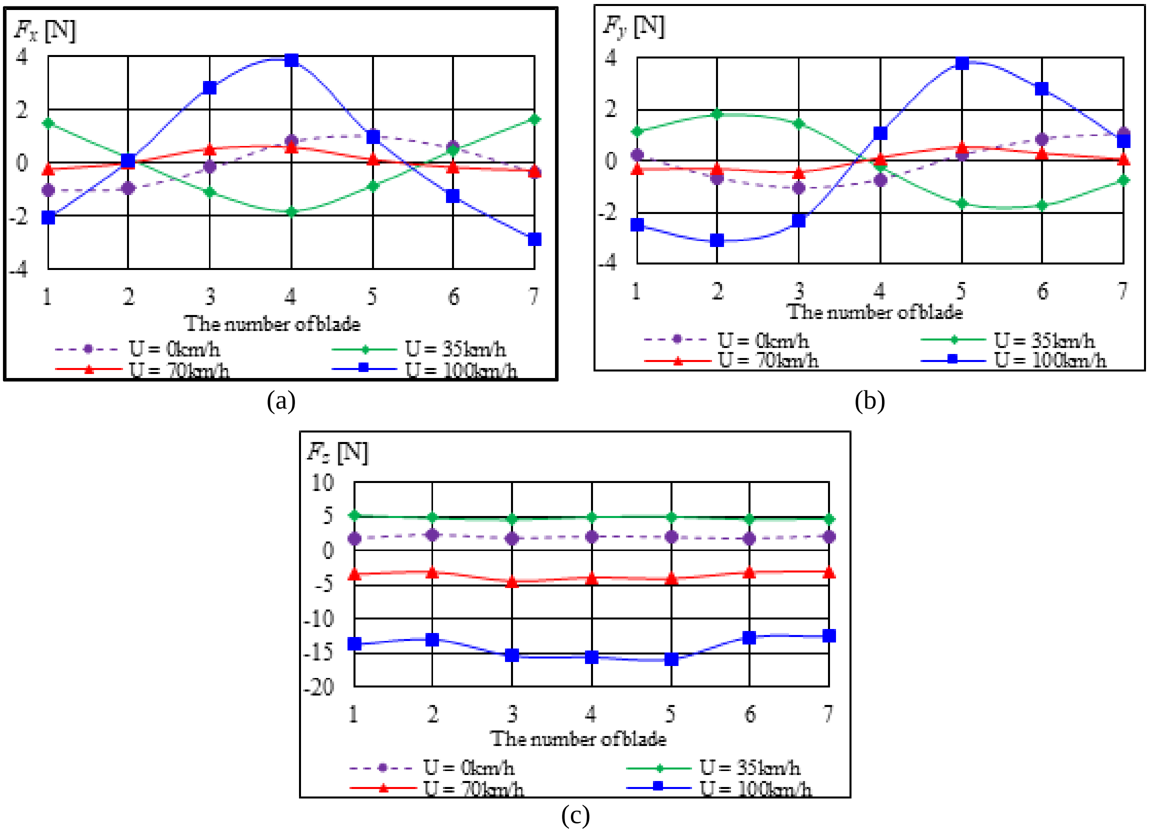

Figure 4. Fx (a), Fy (b) and Fz (c) aerodynamic force components acting on the blade sections.

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Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

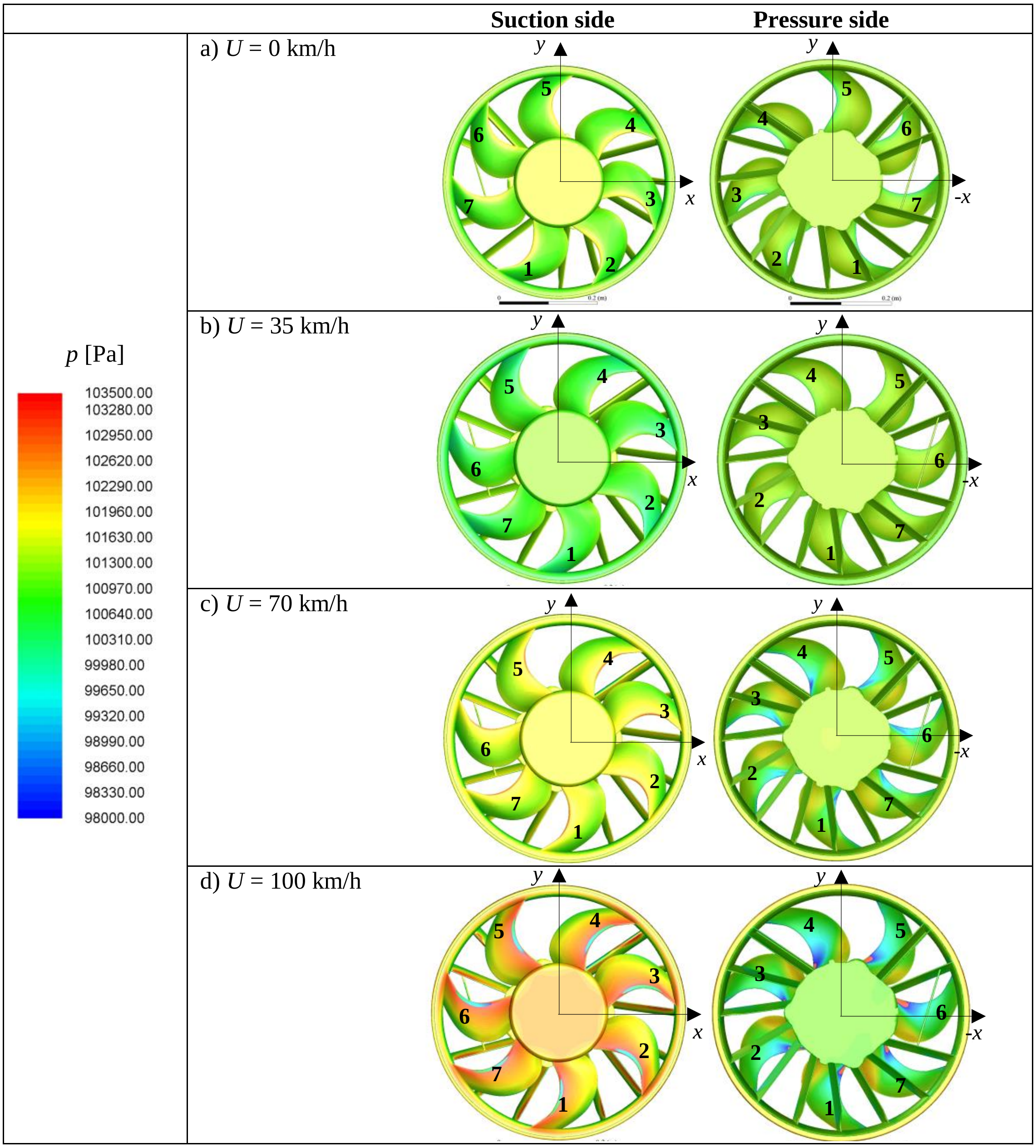

Figure 5. Pressure distribution on the blades for U = 0 km/h (a), 35 km/h (b), 70 km/h (c) and 100 km/h (d)

4.2. The effects of covering plates

Computation is also carried out to investigate the effects of covering on the aerodynamic forces acting on the blades and pressure distribution on the impeller. In this computation the half of the covering surface is 'activated' and the free stream velocity in the inlet cross section is set to zero.

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Figure 6 shows F_x, F_y and F_z force components acting on the blades of the fan. In Fig. 7 pressure distribution on the impeller of the fan is shown. It is seen in Fig. 7 that blades 2, 3 and 4 are fully covered, blade 5 is partially covered and blades 6, 7, 8 and 1 are free of cover. The force component in the axial direction F_z is the greatest (see Fig. 6) which agrees with the results of the previous computations. As seen in Fig. 6 the forces are higher on those blade sections which are behind the covering plate. This means an asymmetric load on the structure which can possibly induce mechanical vibrations of the structures. This asymmetry can also be seen in Fig. 7.

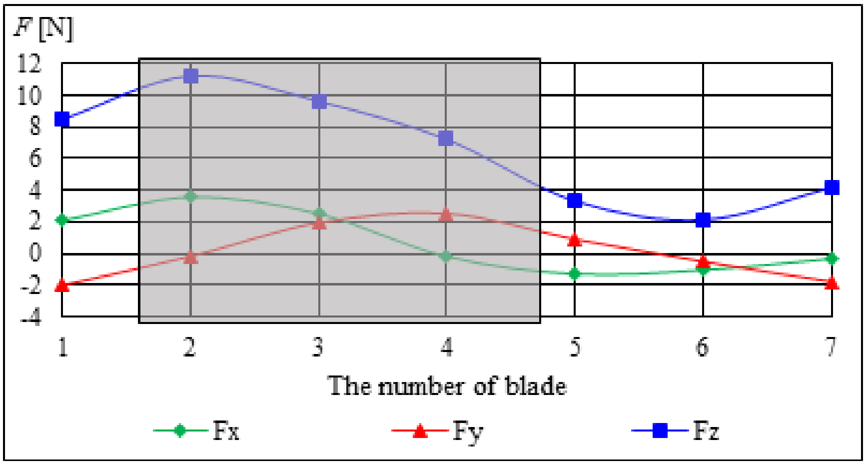

Figure 6. F_x, F_y and F_z force components for cover

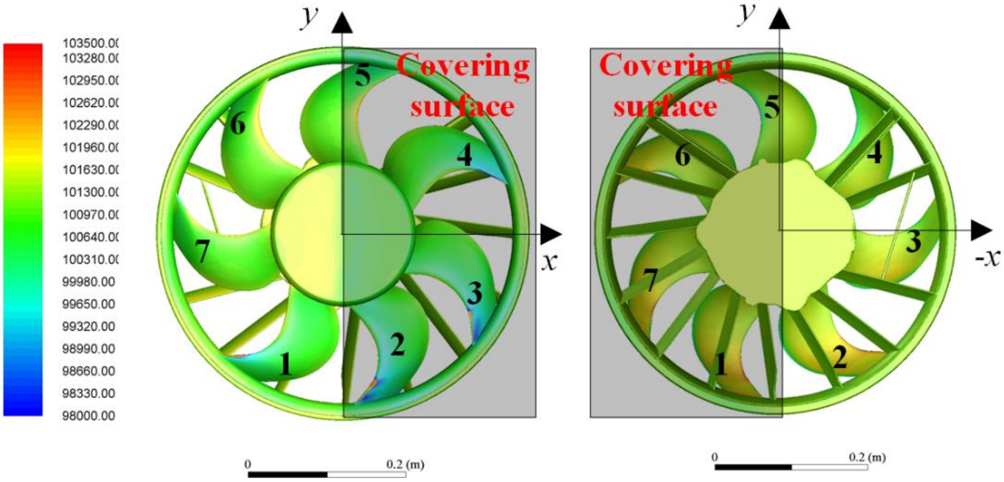

Figure 7. Pressure distribution on the blades for cover

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4. CONCLUSIONS

In this study fluid flow around an axial cooling fan is investigated by means of numerical simulations using the commercial CFD software package, ANSYS Fluent. The rotation speed of the fan was set to a constant value of $n = 2500\ min^{-1}$. The fan is placed into a uniform stream; the free stream velocity is varied between U = 0 and 100 km/h. A covering flat plate is placed on the suction side of the fan which can be 'activated' (satisfying no-slip boundary conditions on the surface) or 'inactivated' (the fluid can flow through it). The three components of aerodynamic force are evaluated on the blade sections. The results obtained are concluded in the following points:

- The results from the computational method are validated against experimental results (using CTA measurement approach) using the time-mean values of u and v velocity components. The comparison between CFD and measurement data showed good agreements;
- Increasing the free-stream velocity, the fluid forces are showed to increase. F_x and F_y can be either positive and negative meaning that the force acts in or opposite to the rotating direction of the impeller. F_x and F_y values for U > 35 km/h increase and decrease in the same location, so that these data sets are 'in-phase'. At the range of U < 35 km/h different tendencies can be seen that need additional computations. It was shown that axial fluid force components F_z is the highest which can also be positive and negative;
- Asymmetric pressure distribution can be seen on the impeller in case the covering flat plate placed on the suction side of the fan is activated. This asymmetry occurs also in the aerodynamic forces; F_x, F_y and F_z are higher on those blades which are behind the cover and lower on those blades which are free of cover.

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CULTURAL DIFFERENCES IN FOOD CONSUMPTION: THE EXPERIENCES OF INTERNATIONAL STUDENTS

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ABSTRACT

There is a great variety of foods eaten. It is obvious that foods play a very important role in the daily lives of individual nations. Foods and meals, however, serve not only the living, but also fulfil other functions in the given society. For example, food expression may be part of a social class, reveal income conditions, and express identity.
The investigation was carried out on the topic by a qualitative method, in the form of an in-depth interview. The interviews were conducted by master students of the Szent István University in the framework of Multicultural Management subject, with non-Hungarian origin. A total of 65 in-depth interviews were conducted between 2017 and 2018. Interviewees were members of 22 nationalities. During the investigations, the main questions were: What type of food do you consume the most? What factors do you take into consideration when choosing foods? What differences do you find in the habits of the different ethnic groups, especially with regard to their eating habits? Most of the interviewees are interested in compare their diet and cultural traditions to other nations' and prefer local foods. The study proved that eating habits in Hungary have an impact on the eating habits of foreign students, and they change them in several elements. The study found that dietary choices are a complex decision that has a significant environmental and social impact but need to say, thanks to the strong cultural background the students can keep their sustainable eating values in abroad.

Keywords: culture, food choice, consumption

1. INTRODUCTION

Several authors [1] [2] have already studied the role of food in the economy and society. Meals and food are an integral part of our daily lives, creating a bond between people. In his study Nagy [2] pointed out that this point of view shows how food creates a shared world view among those who share the same culture.
The role of food and food in culture is evidenced by the fact that in 2014, the Mediterranean diet was added to the repertoire of UNESCO's intellectual heritage of humanity. The list (in a complex way) describes the diet as a combination of crops, harvesting, fishing, animal husbandry, processing, cooking, and especially sharing and consuming food. Mediterranean diet also emphasizes the importance of hospitality, neighborhood, intercultural dialogue and creativity, and draws attention to respect for diversity and the fact that meals are never just about nutrition [2].
Consumer behaviour is becoming increasingly heterogeneous due to cultural differences. This phenomenon makes it increasingly important to understand the impact of national cultures and their impact on consumer behaviour. To understand consumer behaviour, we need to study how individuals, groups, and organizations meet their needs and needs, choose, buy, use, and utilize products, services, ideas, or experiences.
The study of consumer behaviour is based on an analysis of observable behaviours:

- who, what, how much and how they bought
- how the product was consumed,
- individual needs, perceptions
- what information consumers have and how they process them
- how to evaluate alternatives
- how they feel about owning a product

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Food consumer behaviour occupies a special place within consumer behaviour in several respects: on the one hand, it is directly or indirectly related to the survival of man, and on the other is the result of long biological, social and cultural processes, and thirdly the most complex human behaviour. There are several contradictions in the consumer behaviour of the food. Characterized by a paradox: Consumption of food is a source of human well-being and discomfort equally. Food consumed is the basis for health, but it can also cause disease. Another contradiction is the dual behaviour, which can be characterized by different contradictory pairs: simple-complex, biological-psychological, average-unique, general-special, individual-corporate, casual-festive, planned-random, and so on. There is interest in new foods and fear of the new in food consumer behaviour.

The models of food consumer behaviour are built on three components:

- on the one hand, the food itself, along with the physical, chemical and biological properties that trigger physiological effects and needs,
- on the other hand, the customer, the person of the consumer, who perceives food and the surrounding environment through sensory perception, psychological factors,
- thirdly, an economic and social environment that is an external condition for the consumer [3].

Many models of cultural differences were studied in literature. The purpose of cultural models is to make the individual elements and the they can be used to compare the cultures studied and draw conclusions about dominant values [4].

When examining the economic factors that influence food consumer behaviour, it is primarily the incomes and prices that must be taken into account, as well as the structure of consumer spending. Income affects food consumption in several ways: on the one hand its size, its structure, the breadth and depth of its choice. For example, the share of food in the expenditure structure of older people is higher. In this age group, the need to preserve health and reduce the risks associated with nutrition is particularly appreciated. However, domestic experience shows that older people - because they have weaker purchasing power - prefer lower-priced, less valuable food [3].

In the case of sociological factors, consumer behaviour is strongly influenced by all the groups to which the individual is a member or of which he or she wants to be a member [1].

The family is a special group that is a collective decision-making and business community. Food choices are based on family traditions, the individual's eating habits are acquired by the family and will have a decisive impact on life. Households are the consumers of most products, and many members of the household can make their decision to buy a product. The family also plays a significant role in the development of nutritional habits and a healthy lifestyle. Opinion leaders are those who, in informal communication, provide advice or information about a product or product group, how many brands, which brand is best, or how the product can be used [4]. In the case of foods, doctors, athletes, nutrition advisors play a role as opinion leaders, who usually exert their influence on the flow of information within informal groups. Psychological factors determine the individual's acceptance or rejection of certain foods, or the weight or role of accepted foods [4]. Among the psychological factors influencing consumer behaviour, the personality, activating factors (motivation, attitude) and cognitive factors have to be examined. Activating needs are linked to an individual's internal tension and act on the consumer's behaviour through the following connection system: Emotion → Motivation → Attitude → Behaviour.

Biological factors provide consumers with the energy resources they need to function and the building elements of their body during their nutrition. Another outstanding biological function of nutrition is that it affects the senses. Nutrition, in addition to being an indispensable function, carries a threat. Nutrition appears as a source of danger due to inappropriate nutrition or consumed food.

Another problem is that, instead of natural foods, the consumption of semi-finished or finished products produced by the industry has come to the fore, unilateral consumption of which does not provide full nutrition. There are cases where some of the diseases caused by food consumed have a negative effect in a short time (such as food infections, food allergies).

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Nutrition can also be responsible for a disease not directly caused by a particular food, such as illnesses caused by inappropriate lifestyle and eating habits (vascular diseases, diabetes, cancerous diseases). Nutrition problems are also reflected in the values of the Hungarians' health.

Cultural / Anthropological Factors: Culture According to Hofmeister-Tóth (2003), it is "the totality of the learned beliefs, values, and habits that guide consumers' behaviour in a given society." [5] Values, value systems, as carriers of cultural features, help the individual to choose a behavioural pattern that matches his personality traits. Values and lifestyles are highly determinative of human core behaviour and thus of consumer behaviour. However, different values for different consumers may have different meanings, such as social values (love, family), religion, money, beauty, youth, etc. [4]

According to Lehota (2001), culture is the most complex, decisive concept and relationship among factors influencing food consumption. The essence of which is that it is the result of a learning process, shared features by the society and the members of the group, which originate from the past and contain components that are inherited by generations, as a combination of components shared by social institutions. [1] Szakály et al stated [6] that the level of culture evaluation can be country group, country / nation, region, ethnicity. Culture, as an environmental factor, determines what counts and classifies food in a given society: holy food-everyday food, food as medicine, and food as a symbol of group and individual identity.

In my study, I demonstrate the role played by the elements of culture in food consumption, what differences can be observed in the food consumption of different populations, and that how cultural factors such as value, religion, traditions, ceremonies, etc. affect eating habits. I present a qualitative research method to show the role of food consumption in the culture of several ethnic groups and to introduce how cultural factors influence the eating habits. The research is devoted to exploratory research, which provides a good basis for later quantitative research.

2. MATERIALS AND METHODS

My study was conducted in the form of a qualitative method by means of in-depth interview. The research is intended for exploratory research that provides a good basis for future quantitative research.

The interviews were conducted by the graduates of Szent István University's foreign and Hungarian leadership and organization in the framework of the Multicultural Management course with persons of non-Hungarian origin. A total of 65 in-depth interviews were conducted between 2017 and 2018. The language of the interviews was different, based on the language of the interviewee who was best able to communicate with the interviewer. In most cases, this was English. The length of the interviews was on average 50 minutes, and the length and language of the transcripts were very varied. As it is a qualitative research, we used qualitative methods: content analysis. Demographic data were quantified where possible. The persons interviewed came from 22 nationalities, most of them named Hungary as their current residence at the time of the interview. Interviewees who did not live in Hungary were typically Skype or telephone interviews.

The interview was conducted based on an interview guide. Audio interviews, transcripts and translations were made of the interviews. Table 1 shows the structure of the interview. This study does not cover all the topics examined in the interviews; it is limited to only one part that we consider important.

DOI: 10.14232/analecta.2019.1.56-63

Table 1. Structure and Purpose of the Interview Scheme

Sections	Goals
I. The aim of the research	Presentation of the purpose of the research, informing the participants, providing anonymity, recording
II. Introduction	Obtaining demographic data (age, nationality, residence, family, friends, leisure)
III. Consumer habits	Main food types, frequency of consumption, diet of special diet, special foods, way of preparing food, ceremonies, food role
IV. Food choice	Influence factors, quality, label, risks, traditional vs. new foods
V. Culture and food consumption	Interpretation of the concept of culture, values, ethnic groups, travel, relationships, cultural knowledge
VI. Summary and conclusion	Summary of thoughts, deduction of conclusions

3. RESULTS AND DISCUSSION

3.1. Characterization of the sample

The interviewees were members of several ethnic groups (Figure 1); most of the people came from Germany (7 people), China (6 people) and from the neighbouring country: Poland (5 persons), Romania (5 persons), Slovakia (5 persons).

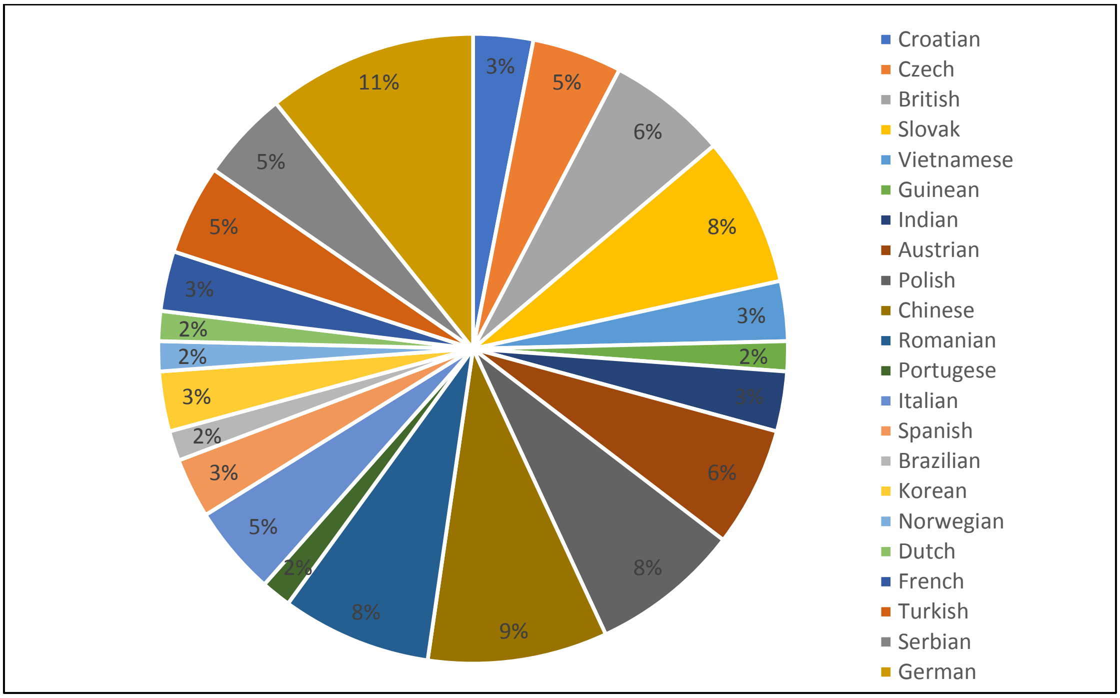

Figure 1. The distribution of participants based on nationalities, percent

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Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

Regarding the gender ratio, the majority of the interviewees were men (70%), while the ratio of women participated in the interviews was 30%.
Figure 2 shows the frequency of people participating in the interviews by age group. It turns out that the majority of the interviewees come from the 18-29 age group, and the 30-39 age group is also represented in large numbers.

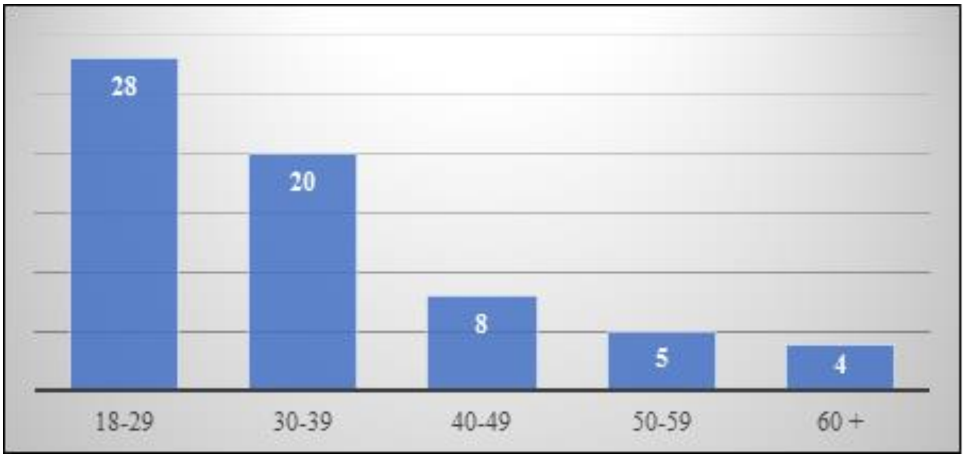

Figure 2. The number of participants based on age, persons on nationalities, percent

I was also curious about the current location of the participants. As it is shown in Figure 3., the vast majority of interviewees stayed in Hungary at the time of the interview. Rest of the participants stayed at other European destinations.

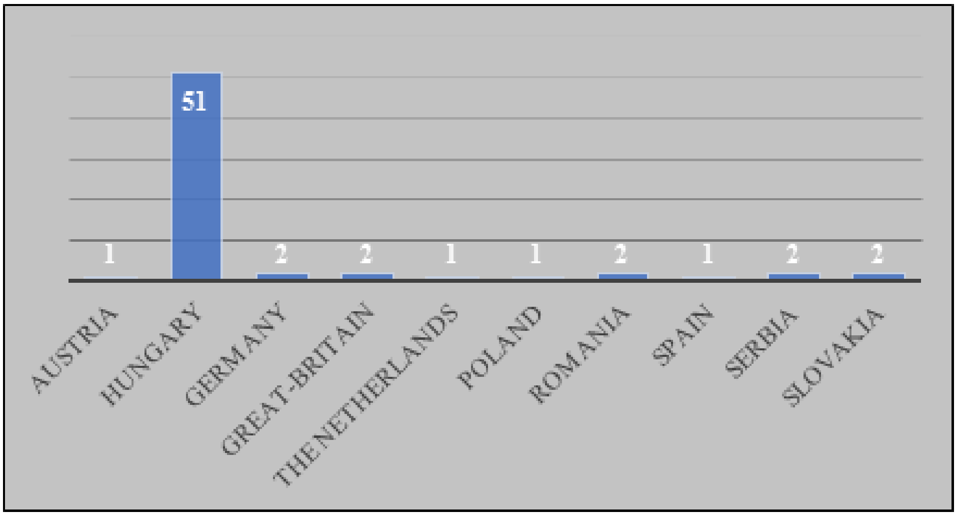

Figure 3. The number of participants based on current place of residence, persons

DOI: 10.14232/analecta.2019.1.56-63

3.2. The results of the interviews

The interpretation of the word culture

As in literature, there are many phrases of the word ’culture’, the participants have interpreted the notion of culture very differently, but recurring elements can be perceived, such as traditions, habits, and lifestyles. "Culture is primarily about all of our traditions and customs, including our everyday linguistic expressions, the everyday things that we like to do, the foods we consume, the folk traditions associated with different occasions, and the culture of which is part of people's mentality, what and how do we see it" (Spanish). "It means the traditions and habits of a nation to me: how they live, how they behave, what they do, what their characteristics are in social life and in private, what foods they consume, what their drinks are, what their agenda, and so on" (English). "For me, culture is a way of life that a group of people follows from generation to generation" (Guinean).

Some interviewees believe that culture is a set of traditions inherited from generation to generation. "Culture is a set of habits and traditions that this generation produces and delivers to future generations." Among the interviewees, there were those whose appearance, the look of the culture, is "the habit of others, their dressing, the behaviour and the speech, looks" (Serbian).

Main food types

The food varieties favored by the interviewees show a very varied picture. However, the participants are eager to eat vegetables, meat and fish. Of course, the local, traditional food is present in the nutrition of almost all participants. At the same time, several interviewees explained that he would like to try other nations' food.

“In my culture, people usually consume fish or some Mediterranean food. I also love fish, rice, meat and vegetables. My family, however, eats any food: we usually eat lots of fish, potatoes, vegetables and pasta. “(Italian)

"For the older generation in the Netherlands it is very important to eat meat every day: one day pork, the next day cattle, then chicken. They eat mostly beef and fish. Typically, olive oil or cooking oil is used to prepare food. The Dutch tradition is the raw herring that is used locally on the market with onions. The typical food on the local market is the fish fillet fried in the flour, with egg-mayonnaise sauce and garlic. The french fries are often eaten with a special spicy ketchup, curry ketchup. Mustard is mainly used for sausages and fascizas. The sausage is made from pork “. (Dutch)

Factors affecting food consumption

The question of what factors are taken into account in the selection of foods has been the main concern of the interviewees as regards food freshness. Interviewees also considered the quality, taste, smell, texture and color of foods to be important.

“It is very important for meals that the meat and vegetables are fresh. In the case of durable foods, it is important to contain as little sugar as possible and to avoid any coloring matter or additives. “

Another important factor in the selection of foods was origin, expiry date and packaging.

Values in life and food consumption

During the interviews, the most frequently quoted values were family and health, which the interviewees had repeatedly contacted with food consumption.

"Of course, children are the greatest gift in their lives. In addition, love for nature is very important and health. "They love to walk in nature and play sports, so it's important to be healthy."(Austrian)

"For me, the main value is health and trying to get the maximum out of our lives, the more we get to know the world, the more people we get to know, the exit from our comfort zone.” (English)

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"Family and health. I can clearly emphasize these two things. Both of the values I have formulated are related to food consumption, because we love eating the most together with the family and what food we consume is very important from the health point of view. the most preferred Italian and Spanish cuisine is basically fresh and healthy food, both of which are basically light ingredients. "(Spanish)
In addition to family and health, for others, love, friendship, honesty, truth and respect are the most important values. “good human relations” was also a decisive value for some interviewees.

The role of food and eating in culture
Many (mainly Far Eastern, African) interviewees show that the quantity and quality of food and food consumed also express social affinity:
“Food plays a very important role in our culture, because it tells us what ethnicity or what denomination it belongs to. Women celebrate more holidays, offer food in large pots, sit around people, and eat by hand. ”(Guinea)
“The lack of food is a sign of poverty, and Vietnamese are reluctant to show it. "(Vietnamese)
“Meals are definitely central to Chinese culture and everyday life. I'm Chinese, so I grew up on authentic Chinese food and still eat. My wife is almond, but there is no significant difference in the taste of her and my family's recipes. Perhaps this is because we are both North Chinese, and cultural differences typically come from North-South division, or have a different culture in certain minority areas such as Ujghur Province or Sichuan. “ (Chinese)

The relationship between food and culture
During the interviews, I also examined the experiences of the participants with regard to cultural differences, and the differences between their own culture and the food consumption habits of other nations. In terms of results, I received very different but interesting opinions:
“People's habits are usually determined by their culture, because it shows how their daily life takes place, what they eat, what their religion is, how they behave in certain situations. For example, there are those who shout during a conversation, it was very strange to me. A striking difference is that in many African countries, more people still eat by hand in a pot, and in Europe, everyone eats with their own cutlery. ”(Guinea)
"Vietnamese like to eat in large groups while talking long. It is not common in Hungarian culture" (Vietnamese)
“Well, as we talk about food, the kitchen is definitely part of culture, as are many other things like language, humor and the way people usually approach a culture of life. For example, our Italians are much looser, while Hungarians are much more serious! ”(Italian)
“In southern countries, such as Italy, Greece, people are thinking strangely about life: they are not in a hurry, they do not enjoy and enjoy life. ”(Polish)
"I can compare Hungary and Portugal. I think people are not as nice here as in my own country. But night life is much better than we do. (Portuguese) "
“In France, people eat very slowly, while the Italian people eat late at night. (Korean). In Korea it is a disgrace if someone speaks while eating. However, in other countries this is completely accepted. "(Korean)
"Every nation and nation has its own habits that can be observed in everyday life, in private life and in the workplace. I do not consider myself a very good observer, but these are usually quite clear and conspicuous things. relatively mixed nation), regularity is important in us, we love the routine, we are not too personal, although it also depends on the personality, but with the Dutch who are loose, direct and much more flexible. Mentoring is very typical for work, while in Switzerland, flexibility is almost an unknown concept. (English living in the Netherlands)”

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4. CONCLUSIONS

In my research, I examined the cultural differences inherent in food consumption through in-depth interviews prepared by university students. In the study, I have applauded the fact that interviewees interpret the notion of culture in a very diverse way, while observing recurring elements in interpreting the concept, such as tradition, customs and lifestyle. It was evident that food plays a very important role in the daily lives of individual nations. At the same time, food and meals serve not only the maintenance of life but also other functions in the society. For example, food can be an expression of belonging to a social class, it also discloses income and expresses identity.
However, I must emphasize that my research was intended for exploratory research with the primary purpose of learning about cultural factors that affect food consumption. On one hand, the results of the research can help marketing professionals to better understand consumer behaviour and, on the other hand, serve as a basis for a later, representative quantitative research.

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Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

SENSORY EXAMINATION OF HONEY AND THE EFFECT OF SENSORY CHARACTERISTICS ON PURCHASE DECISIONS

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ABSTRACT

Aside from honey's sweet and distinctive flavor, it can provide various human health benefits, which makes its market value favorable compared to those of other sweeteners. In the study, the purchase decision making process is examined through sensory experiments. The results are based on sensory analysis of 600 adult consumers, which show that, consumers' demand for honey varies significantly according to the flavor, aroma, color, texture and price. The geographic location of the honey's production and the product packaging are key factors for some consumer segments. Sensory differentiation and the evaluation of honey quality are different in the analyzed consumer segments, which are described in the study.

Keywords: honey, sensory examination, purchase decision, quality, consumer behavior

1. INTRODUCTION

The popularity of honey has been increasing worldwide mainly due to the increasing trend of healthy lifestyle, eating functional food, and local food consumption. In recent years, food market has been influenced by growing consumer interest in healthy lifestyle including healthy eating habits. Consumers are more concerned about their health and prefer to purchase natural and healthy food [1]. According to the Hungarian Central Statistical Office the consumption patterns of honey in Hungary are slowly changing. Since 2010 the annual consumption per capita has increased from 300 grams to almost 800 grams by 2018, which represents approximately a 170 percent increase in the mentioned period [2].
Due to increasing consumption, honey market in the European Union and in Hungary is flooded with cheap imported honey. Approximately 40 % of overall consumption in the EU is covered by import from third countries. The European Union is the world's second biggest producer of honey after China. Every year, about 600,000 beekeepers and 17 million beehives produce about 250,000 tonnes of honey. However, the production does not cover the demand: about 200,000 tonnes of honey were imported into the EU in 2016, mainly from China, which accounts for about 40% of EU imports [3]. Compared to their competitors elsewhere, EU beekeepers face relatively high production costs and the limited EU exports are priced higher than imports into the EU [4]. In general, imported honey does not have precise country of origin due to legislation, which maintains labelling rules which allows producers to indicate the honey origin [5]. There are significant differences in quality between honey products, and consumers find difficult to differentiate the honey products [6]. In the study the different honey characteristics are examined in three consumer segments.

2. MATERIALS AND METHODS

The aim of the research was to identify consumers' perception of intrinsic attributes (sensory qualities) between different types of domestic honey in the absence of extrinsic attributes (price, country of origin, brand, label, and producer). Primary data were obtained by experiment with blind sensory testing on the sample of 600 respondents which evaluated 11 different types of local honey.
The sensory examination lasted from the beginning of September to the end of December 2015 in four locations: in Budapest, Gödöllő, Szigetszentmiklós and Kerepes. During the examination we applied simple random sampling technique. The participants of the sensory examination were asked to taste 11

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Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

varieties of honey from the 2015 Kincses-Billege Beekeeping production. The tested samples were: acacia, mixed flower, silkworm, linden, chestnut, linden-chestnut, forest, pine, sunflower, rape-fruit and hawthorn honey.
After tasting all the different honey samples, the respondents selected the most preferred sample and which sensory characteristics were indicated their decision: taste, color, scent or texture and there was the price as other option. Consumers could choose all four properties, and they had to mark at least one of the characteristics.
The demographic character and other characteristics asked in the survey were gender, age, professional competence, and price sensitivity. Price sensitivity is indicated on a scale of 1 to 5. On the basis of professional competence, the respondents were divided into three groups: average consumers, demanding consumers and expert consumers. On the basis of professional competence, the respondents classified themselves into the certain category. An average consumer was defined as a consumer, who buys honey in case of illness, but at least every year once. Demanding consumer, who consumes several types of honey regularly throughout the year. Experts were defined as consumers, who consume several types of honey regularly throughout the year and has a knowledge on different honey types and is able to recognize the taste differences between the types of the honey.
Demographic characteristics asked during the study were sex, age, expertise in honey and price sensitivity. On the basis of expertise in honey, we divided the respondents into three groups: average consumers, demanding consumers and experts. An average consumer buys honey at the time of illness, but at least once every year. The demanding consumer consumes several types of honey regularly throughout the year. Price sensitivity is indicated on a scale of 1 to 5.
In the sample 57.2% of the respondents were women and 42.8% were men. According to the data of the Population Census 2011 of the Hungarian Central Statistical Office [8], the proportion of women in Central Hungary was 53.2%, while that of men was 46.8%, which in our sample was 3.94% in favor of men. The respondents were classified into 7 age groups with the differences from the representative ratio included in Table 1.

Table 1: Ratio of population in Central Hungary region in reality and in the sample

Age groups	Ratio of population	
	in reality	in the sample
0 – 18	14.08%	1.00%
19 – 25	11.64%	8.83%
26 – 35	15.47%	14.33%
36 – 50	22.03%	34.17%
51 – 62	17.16%	28.50%
63 – 75	12.24%	9.50%
75 and over	7.39%	3.67%
Total	100.00%	100.00%

Source: HCSO and own survey

Respondents were classified into three categories according to their expertise in honey: average consumer, demanding consumer and expert consumer. The majority of the respondents had an average level of expertise, 281 fell under the category of average consumer. 278 were demanding consumers, they had more expertise than average consumers, but they were not professional of honey. An additional 41 people participated in the research, who were experts on the topic.

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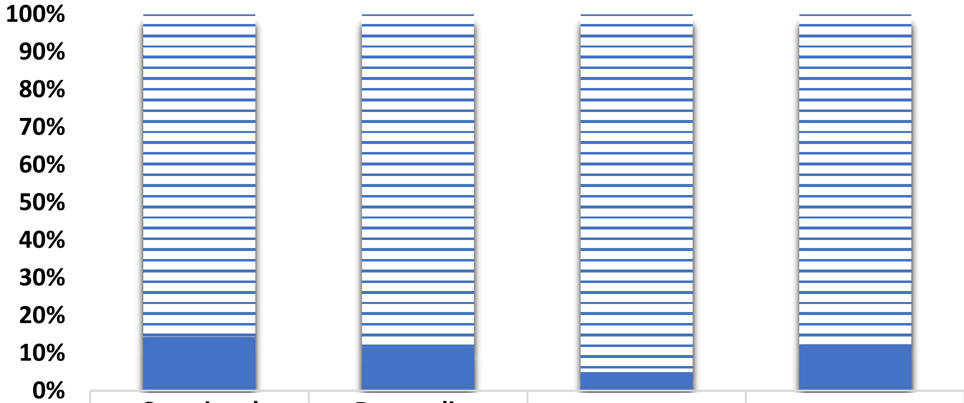
On the basis of price sensitivity, the participants in the research were divided into three groups: 30.5% were highly price sensitive, 13.5% were price sensitive, 24.7% were classified as neutral, 11.3% was less price sensitive, while 20% was not price sensitive on their own.
The study was conducted in four locations: Budapest, Gödöllő, Szigetszentmiklós and Kerepes, the respondents were all residents of Central Hungary region: 405 people in Budapest, 66 in Gödöllő, 107 in Szigetszentmiklós and 22 in Kerepes.

3. RESULTS AND DISCUSSION

In the study the taste, color, scent and texture were examined in the three consumer segments as evaluation characteristics. We examined the consumer decision making process on 11 different taste sample.

3.1. Evaluation of honey characteristics

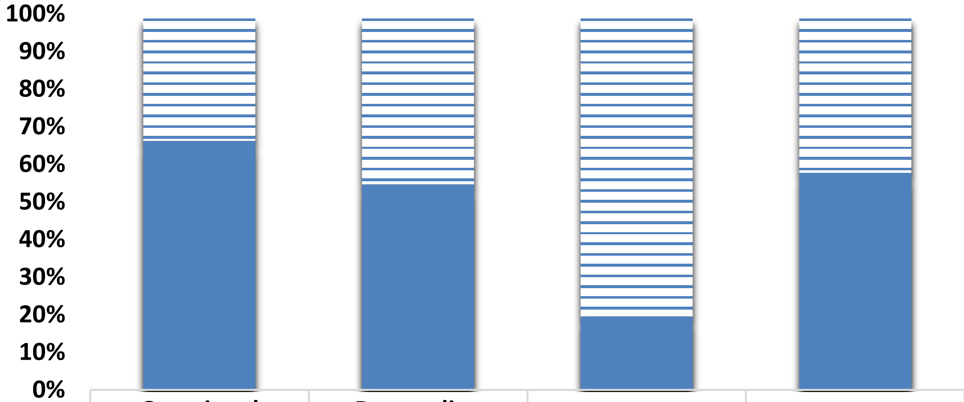
Based on the results of the chi-square test (p = 0.20), with the significant level of 0.05, there is no significant difference between the groups of consumers in judging the importance of the taste. (Figure 1) More than 85% of the average consumer, the demanding consumer and the expert groups consider the taste to be an important sensory aspect. The experts almost all agreed that the flavor is the most significant sensory characteristic of honey, but they also marked a higher proportion of other characteristics than the groups of average and demanding consumers, which can be associated with their high sensory skills.



	Occasional consumer	Demanding consumer	Expert consumer	Total
Yes	85.8%	88.5%	95.1%	87.7%
No	14.2%	11.5%	4.9%	12.3%

Figure 1: Taste evaluation of different consumer segments

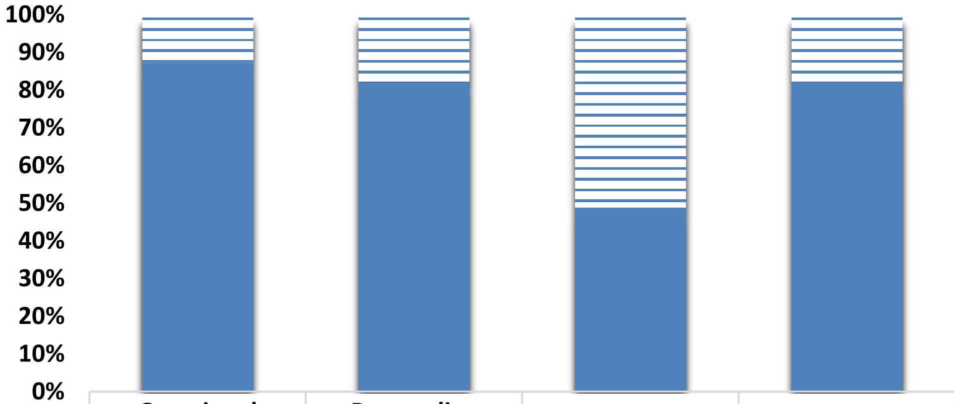
Based on the result of the chi-square test (p <0.01) at a 0.05 significance level, there is a significant difference between consumer groups in assessing the importance of color. More of the demanding consumers consider the color important than in the group of average consumers, but the majority of average and demanding consumers do not consider the color very important while the majority of experts consider the color of honey to be particularly important (Figure 2). This can be paralleled with the expertise of the consumers. The more the consumer understands the product, the more aspects he takes into account when deciding on it. After the taste the color proved to be the second most important characteristic.



	Occasional consumer	Demanding consumer	Expert consumer	Total
Yes	33.8%	45.3%	80.5%	42.3%
No	66.2%	54.7%	19.5%	57.7%

Figure 2: Color evaluation of different consumer segments

Based on the result of the chi-square test (p <0.01) at a 0.05 significance level, there is a significant difference between consumer groups in assessing the importance of scent. 12.8% of average consumers, 18.0% of demanding consumers, and 51.2% of experts chose the scent as an important sensory characteristic, as shown in Figure 2.



	Occasional consumer	Demanding consumer	Expert consumer	Total
Yes	12.8%	18.0%	51.2%	17.8%
No	87.2%	82.0%	48.8%	82.2%

Figure 3: Scent evaluation of different consumer segments

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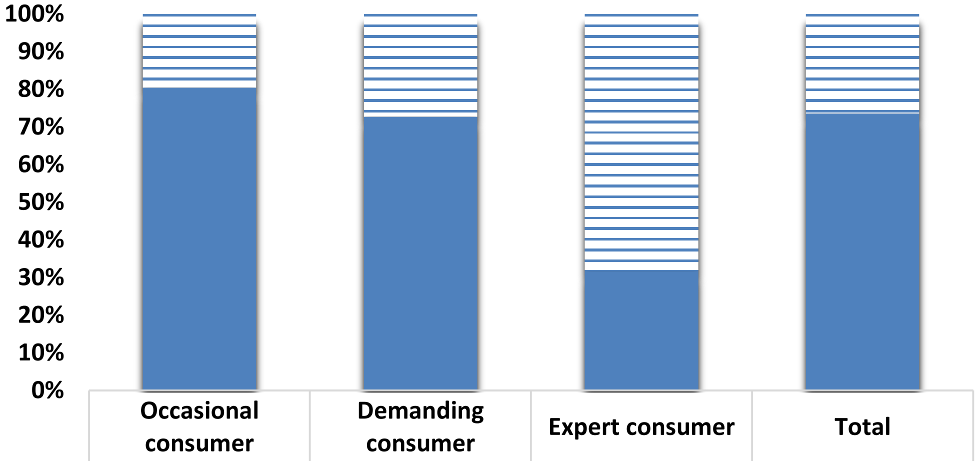
Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

The high proportion of the expert consumer group can also be explained by expertise, as is the case with other sensory characteristics. In terms of scent, it is important to mention that this was the least important aspect of sensory characteristics.
The result of the chi-square test (p <0.01) at the 0.05 significance level shows a significant difference between the groups of consumers regarding the importance of the texture. A small part of occasional and demanding consumers consider the texture to be an important sensory characteristic while the majority of experts does so (see Figure 3). The majority of the respondents considered texture to be the third most important feature after color.



	Occasional consumer	Demanding consumer	Expert consumer	Total
Yes	19.6%	27.3%	68.3%	26.5%
No	80.4%	72.7%	31.7%	73.5%

Figure 4: Texture evaluation of different consumer segments

In the case of all three groups, the taste was the most important sensory aspect, followed by color, then texture and scent. A total of 87.7% of the respondents chose the taste as important sensory characteristics, 42.3% of the respondents considered the color, 26.5% considered the texture while only 17.8% considered the scent important. There is a significant difference in the perception of consumer groups in terms of color, scent and texture, as shown in Figure 1-4. When evaluating honey, consumers take into consideration more and more sensory aspects with increasing expertise. For occasional consumers, it was only the taste that prevailed, while a higher percentage of demanding consumers took more considerations into account when choosing. For the experts, all four attributes were significantly more important in making the decision than in the other two groups.

3.2. Evaluation of honey varieties

Based on the result of the chi-square test (p = 0.83), at a significant level of 0.05, there is no significant difference between the consumer groups in evaluating the honey varieties. The distribution of consumer groups by honey variety is presented in figure 5, which illustrates that there is no significant difference between consumer groups regarding the preferences on varieties.

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Analecta Technica Szegedinensia
Vol. 13, No. 1 ISSN 2064-7964 2019

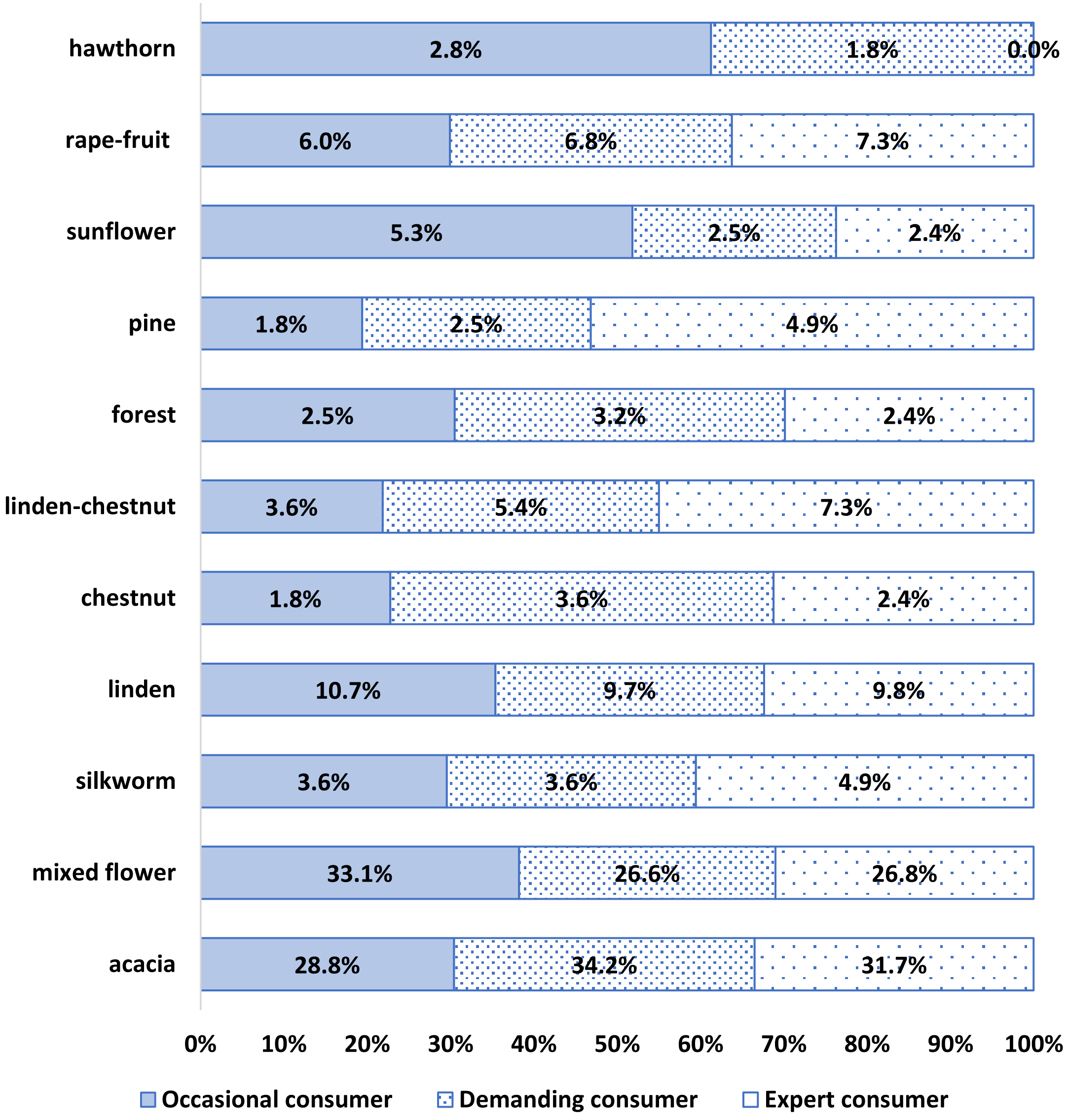

Figure 5: Evaluation of honey varieties in different consumer segments

Distribution of the popularity of honey varieties by all consumers is as follows: Acacia was the most popular with 31.5%, followed by mixed flower with 29.7% and linden by 10.2%. 6.5% of the respondents favored rapeseed, 4.7% of them linden-chestnut, 3.8% of them sunflower, and 3.7% of them silkworm honey. Less than 3% of the respondents preferred chestnuts, pine and hawthorn honey, see Figure 6.

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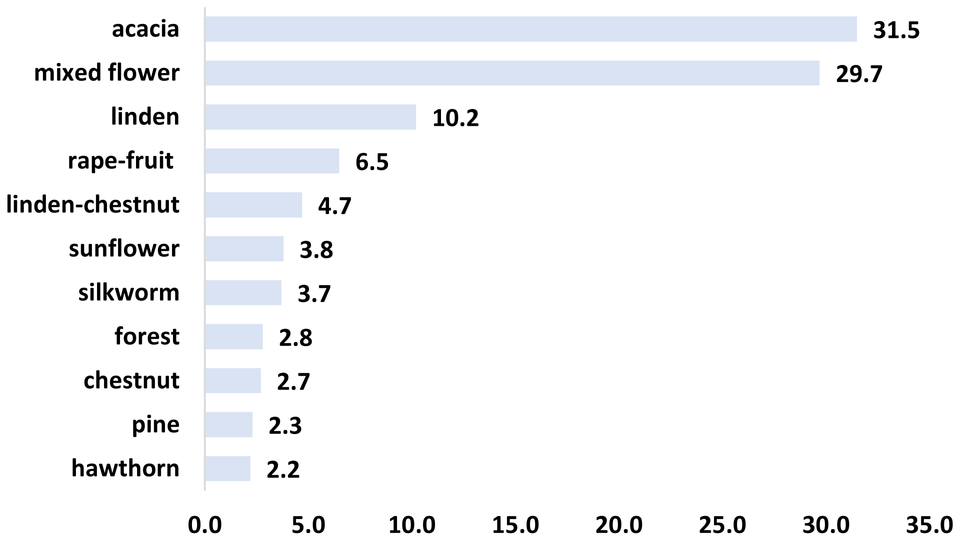

Figure 6: Distribution of the popularity of honey varieties by all consumers

Based on the results of the chi-square tests on sex, with 0.05 significance level, there was no significant difference between the perception of the sensory properties of the sexes and the honey varieties. For both sexes, taste is the most important sensory characteristic.

4. CONCLUSIONS

In conclusion, consumers in Hungary increased their consumption from 300 grams to almost 800 grams by 2018. We examined the differences in consumer preferences on honey taste, color, scent and texture. The consumers prefer the taste of monofloral honey acacia, the second most preferred taste is the mixed floral honey. After the third taste, which is linden the following tasted are less preferred, under the 5 percent of the consumers would buy those honey. There are significant differences between consumer segments in preferring honey tastes. The most important criteria in purchase is taste. Color, scent and texture is significantly more important to the expert consumers, who eat more varieties of honey regularly. The results of the study shows that, there are some highly preferred taste of honey which are preferred in all segments of customers.

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Analecta Technica Szegedinensia

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CHANGES IN THE LEGAL AND SUPPORT BACKGROUND OF WOODY ENERGY PLANTATIONS

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ABSTRACT

Current forestry laws and regulations are not applicable to woody energy plantations. The cultivation technology used in these plantations differs from ones used in conventional forest management; thereby, specific legislation to regulate cultivation in woody energy plantations is required. Hungary passed its first regulations for woody energy plantations in 2007. The legislation addressed permitting, range of plantable species, planting procedures, cultivation, and plantation harvesting. The legislation overregulated coppice technology and only targeted roundwood energy plantation. The legislation does not mandate forest site surveys and its related expert opinions despite their importance in plantation establishment, particularly regarding tree species selection. The latest legislation, which improves earlier deficiencies and prescribes planting-execution plans for all plantations, came into effect 2017. Another important change is the industrial purpose categorization of woody plantations, which appeared beside coppice and roundwood energy plantations. In addition to raw material production, this type of plantation also increases the carbon sequestration of agriculture. The availability of financial resources heavily influenced plantation area size and planting intensity over the years. Investigating plantation tendencies provides an opportunity to identify forms of support that play an important role in creating the conditions for rational land use. Our research presents the effects these changes in legislation and financial support have had on energy plantations.

Keywords: woody energy plantation, law, subsidy

1. INTRODUCTION

In addition to conventional biomass, there is an increased need for plants grown specifically for energy purposes to meet the growing demand for energy and to reduce dependence on fossil energy sources.

The National Energy Strategy 2030 proposes a two-pole agriculture in Hungary with the establishment of an incentive and support system that allows for biomass cultivation for energy purposes. The energy sector can efficiently integrate raw material such as dendromass from woody energy plantations, which currently plays the most important role in the renewable raw material supply of power plants and heating plants. Nevertheless, dendromass cultivation must avoid conflict with food and feed crop cultivation and is only feasible if it meets sustainability criteria. In light of this, emphasis should be placed on woody energy plantations because they can be cultivated on arable fields according to Decree 135/2017 (VI.9.). The literature supports establishing woody energy plantations on low-quality agricultural areas with the provision of appropriate tree species selection and careful soil preparation [1]. Examples of low-quality agricultural areas include drought and flood-affected areas, abandoned grasslands with shallow crop layers, and areas prone to erosion and deflation [2][3][4].

Moreover, experiments have proven that mining areas awaiting re-cultivation and denominated areas affected by red sludge pollution are also appropriate for short-rotation woody energy plantation cultivation [5][6][7]. According to some researchers, poplar and black locust plantation yields can attain a maximum 3-4 t / ha / year in these areas; other research proves average yields or higher are possible with some tree species [8][9][10][11]. Energy plantation legislation, including the obligation to prepare forest site exploration and related expertise, becomes important in this regard. These measures ensure the choice of appropriate tree species / variety to be planted in the area. The cultivation of woody energy plantations plays a significant role in reducing greenhouse gas emissions in the energy sector [12][13].

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The economics of woody energy plantations are questionable [14]; therefore, planned intensive plantation establishment has been lacking in the past. Prior to 2005, woody energy plantation experiments were conducted on 50-60 hectare plots. Planting 5-10 thousand ha of short rotation coppice as planned in 2005-2006 would have resulted in approximately 60,000 hectares of woody energy plantations by 2010 [15]. The Thesis of New Hungarian Energy Policy [15] recommends the forest area be expanded with energy plantations in the period of 2012-2030, which implies the necessity of the planting of 210-230 thousand ha of energy plantation. Marosvölgyi (2005) claims 150 thousand ha of woody energy plantation can be planted [16]. Gockler (2010) calculates 100-250 thousand, but states up to one million ha woody energy plantation can be established by 2020 [17]. Garay et al. (2012) puts this number at 200 thousand ha while Scultety and Seiffert (2009) estimate 300-400 thousand ha of woody energy plantations in Hungary in the long term [18][19]. Over the past few years, the trend toward the realization of the planned plantation areas has been decreasing (Figure 1.)

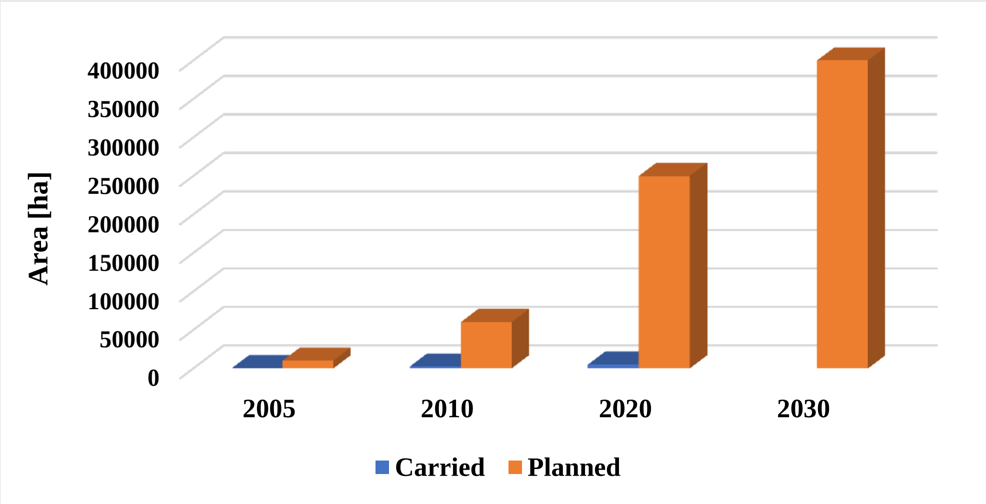

Figure 1. Implementing woody energy plantation compared to planned projections [15][17][19][20]

2. MATERIALS AND METHODS

Woody energy plantation data in Hungary have been available since 2009. We evaluated previous research by comparing it to the available literature. We then contacted the Forestry Directorate of the National Food Chain Safety Authority (hereinafter referred to as the NÉBIH) to acquire current data. With the data provided, we assessed the situation of woody energy plantations for the period 2009-2018.
The official statistical data provided indicates a smaller area of woody energy plantations than practitioners report. Nevertheless, the data processing from official sources was part of this research. Initial regulations concerning woody energy plantations came into effect in Hungary in 2007.
The present study comprises a survey, analysis, evaluation and the conclusions drawn regarding the legal background from 2007 to the present. The financial opportunities to support solid biomass utilization are many, but the currently available sources of support are extremely limited.
This study reviews the background of the direct and indirect support possibilities of woody energy plantations with the help of the available plans, action programs, legislation, and websites.

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3. RESULTS AND DISCUSSION

3.1. Legal background for woody plantations

Legislation did not address woody energy plantations before 2007, which lead to the modification of the 1996 LIV. Act (Forest Act). Consequently, woody energy plantations are separated from "traditional" forests. Article 4 (2) (h) of the New Forest Act (Act XXXVII of 2009 on Forestry, Forest Protection and Forest silviculture) states: "The force of this Act shall not extend to woody crops grown for energy purposes plantations established under separate legislation.
The authorization of woody energy plantations, sometimes accompanied by a subsidy case, became an official act after 2007. Decree 71/2007 (IV. 14.) addresses woody energy plantations and supplies the authorization for the establishment of woody plantations.
The decree states, "Woody energy plantation is a plant for bio-energy cultivation, it can be plant with specific species or variety according to the specific law with an area of more than 1500 m2".
The law distinguishes coppicing (cutting cycle: max. 5 years) and roundwood tree plantation (cutting cycle: up to 15 years). The Forestry Authority has already supplied the official tasks connected to the planting and ceasing. The planting of the woody energy plantation can only be carried out under license.
The 45/2007 (VI. 11.) Decree issued by the Ministry of Agriculture provides details for the authorization, planting, cultivation, and ceasing of woody energy plantations as well as the administrative service fees for these procedures. The legislation concerns the requirements for the quality of planting material in § 1 of the law: "Certified propagation material generated by a licensed producer can be used." Annex 1 of this Decree contains a list of the basic species authorized in Hungary, which are presented in Table 1.
The above-mentioned legislation also states that coppiced woody energy plantation can only be applied to poplar, willow, and black locust. A plant species owner must supply a certificate to plant poplar and willow plantation. With black locust, farmers must apply to the Forest Research Institute for a certificate.
The certificate must contain the ideal site conditions to plant the species and variety. Planting black locust (Robinia pseudoacacia) in protected natural areas and in the Natura 2000 area is prohibited.
An analysis of the relevant legal background revealed the legislation overregulated the planting regulations for coppicing technology and neglected roundwood technology, which appeared in the legislation as a concept only. At the same time the legislation did not mandate site surveys and related evaluations; nevertheless, both are crucial for planting because they can be used to select the tree species and the variety to be planted in a given area.
Government Decree 135/2017 (VI.9.) was passed by merging and simplifying two older laws concerning woody plantations. In the following, we highlight the key elements of the legislation. According to the "new" regulation, woody plantations can be established from basic species specified in the annex to the Act (Table 1).
The woody energy plantation are classified according to the new Hungarian law:

- rolling energy plantation: there are kept up to 20 years, intended for energy recovery;
- copping energy plantation: there are at most 5 years of rotation, intended for energy recovery;
- woody industrial plantation: for the production of wood raw material. The "energy" aspect has disappeared from the name of the decree and an important point has been added to the base material production, up to now mostly for energy purposes, namely, industrial woody plantations for the production of wood raw material.

The number of the usable species has not changed over the last ten years, but the number of varieties has increased slightly (Table 1).

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Table 1. List of permitted basic species that can be planted in Hungary

45/2007 (VI. 11.) Decree	135/2017 (VI. 9.) Decree
Black poplar /*Populus nigra/* Grey poplar / Populus x canescens/ Trembling poplar / *Populus tremula/* White poplar / *Salix alba/*	Poplar species / Populus spp./
Water willow / *Salix viminalis/*	Water willow / *Salix viminalis/* White willow /Salix alba/
Black locust / *Robinia pseudoacacia/*	Black locust / *Robinia pseudoacacia/*
Common alder / *Alnus glutinosa/*	Common alder / *Alnus glutinosa/*
Common ash / *Fraxinus excelsior/*	Common ash / *Fraxinus excelsior/*
Narrow-leaved ash / *Fraxinus angustifolia/*	Hungarian ash /Fraxinus angustifolia danubialis/
Red oak / *Quercus rubra/*	Red oak / *Quercus rubra/*
Black walnut / Juglans nigra/	Walnut species /Juglans spp./
Norway maple / *Acer platanoides/*	Norway maple / *Acer platanoides/*

The list of basic species should be updated and expanded. Since 2007, there have been ongoing experiments with other species including empress, ailathus, elm, false indigo bush, and Manitoba maple; however, the planting of any of these species is only permitted under the experimental plantation category.
The Decree also provides that woody plantations can only be established in areas of at least 5,000 square meters. This is larger than the 1,500 m^2 area defined in the 2007 legislation. Planting woody energy plantations can be decisive in reducing energy poverty and increasing rural employment [21][22][23]. This is especially true for non-contiguous fallow fields.
Machine cultivation and harvesting is only worthwhile in short rotation energy tree plantations that exceed a few hectares; manual work proves more efficient than machines in smaller plantations [24].
In addition, the high energy demand of machine decreases the total energy balance. The energy demand of feller-chopper machines is nearly twice as high as the energy demand of the manual harvesting [25] thereby increasing the amount of harmful emissions during the maintaining of plantation [26].
Technology of most machinery needed for plantation harvesting can be found first of all in the forest management, which necessitates the development of the machines for farmers who often only rent the machines required. The cost of both is significant. Compared to the previous legislation, the maximum maintenance period of the plantations, increased from 15 to 20 years. This gives greater security for power plants in the raw material supply and offers the possibility of long-term contracts with farmers.
A new element has appeared in the Government Decree: “The presentation of the site conditions of the land to be planted and the appropriateness of the suitability of the wood species to be applied with the data content according to the description of the place of production according to the specific legislation on the exploration of the forest production site”. If we apply this term, it will lead to planting species/variety appropriate to specific sites.

3.2. Support system of woody energy plantations

The following forms of financial support have been introduced for woody energy plantations:
Additional support of energy crops was regulated by 33/2007 (IV.26.) Decree of Ministry of Agriculture. The following restriction has been introduced by this regulation: “The rate of area based additional support for energy crops production will be determined according to the procedure which was laid down in Article 89 of Regulation (EC) No 1782/2003, which may not exceed EUR 45/ha.”

DOI: 10.14232/analecta.2019.1.72-81

The 72/2007 Ministry of Agriculture (VII.27.) Decree described the detailed conditions for the use of financial support from the European Agricultural Rural Development Fund for short rotation coppices planting. This non-refundable financial support could be used for planting until the first harvest. Farmers are only eligible for this aid if the farm size concerned exceeded 4 European Size Units (ESU). The size of the smallest eligible parcel is 1 ha. The maximum amount of financial support is 375,000 EUR per application. The maximum rate of aid is 40% of the total eligible expenditure for all investments, which is increased to 50% for young farmers or if the planting was completed in low-quality agricultural areas, and 60% if both of the two previously mentioned criteria are applicable.
The eligible expenditures were as follows: area preparation, nutrient supply, procurement, storage and installation of planting material, annual maintenance according to the planting stock until the first harvest, fencing, and pavement design. It is important that the producer should have a pre-contract for the purchase of wood chips for at least 5 years after installation. Financial support requests of 15 million HUF or more required a completed business plan. For one table, support cannot exceed

- HUF 160 thousand/ha for black locust planting;
- HUF 200 thousand/ha for non-robinia species planting with coppicing technology allowed by 45/2007 (VI. 11.) Ministry of Agriculture Decree.

The New Hungary Rural Development Program (2007-2013) (hereinafter: NHRDP) also supported the cultivation of woody and herbaceous plants. The NHRDP based on Article 15 § (1) of Council Regulation (EC) No 1698/2005 for support of rural development from the European Agricultural and Rural Development Fund. Within the NHRDP, there were four development areas (axes): the first axis pertained to improving the competitiveness of food processing and the agricultural and forestry sector. One of its sub-axes provided support for the installation of short rotation woody energy plantations.
The Environment and Energy Operational Program (2007-2015) (hereinafter: KEOP) gave priority to support biomass use: "The aim is to support biomass projects for energy production connecting to development of agriculture, primarily based on energy crops and agricultural waste" (KEOP, 2007). This support structure contributed indirectly to the planting of woody energy plantations.
The Green Investment Scheme (ZBR) was the most radical support system for reducing carbon emissions in Hungary. The program only supported activities that reduce greenhouse gas emissions to the greatest extent. The ZBR system also "indirectly" supported the planting of woody energy plantations, for example, to cover the energy needs of wood chip-fuelled boiler in a settlement from a plantation. Farmers are eligible for the current Single Area Payment (SAPS) if they have legal land use on 16 June of the current year and have an agricultural area that meets the following conditions:

- used for agricultural activities or
- mainly used for agricultural activities

SAPS support is available only for eligible area reaching 1 hectare. The eligible area of the planned parcel per claim area unit must be 0.25 hectare. Only a single area payment application is eligible on the same noted parcel.
The 51/2017 (X. 13.) Ministry of Agriculture Decree provides for the establishment of 2017 agricultural subsidy amounts. The amount of the single area payment based on the 5/2015 (II. 19.) Ministry of Agriculture Decree is HUF 227,830,155,170. The eligible area is up to 4,966,738 hectares. An advance payment of up to HUF 32,110 per hectare has been available since October 16, 2017.
From 2015 onward, farmers who receive a single area payment and submit a single application in the current year must comply with climate and environmentally-friendly agricultural practices (greening). The (EU) No 1307/2013 and the 10/2015 (III.13.) Ministry of Agriculture Decree regulate the requirements. The aims of the greening is to preserve existing environmental/natural values and climatic conditions. The amount of support for greening is ~ € 81 per hectare, which is an annual, non-refundable grant.

DOI: 10.14232/analecta.2019.1.72-81

In the case of direct aids, the area-related reduction (digressive) system should be applied, as set out in 5/2015 (II.19.) Ministry of Agriculture regulation. If the annual amount of SAPS exceeds EUR 150,000, a 5% deduction will be applied. More than 176,000 SAPS support will be fully decommissioned, see Table 2.

Table 2. Greening and SAPS support amounts [27]

SAPS support [€]	Supported area [ha]	Sum of SAPS [€/ha]	SAPS withdrawal (degression) [%]	The rate of SAPS per hectare [%]	The rate of greening per hectare [%]
≤150,000	≤~1048	~143	0	100	100
150,000-176,000	~1048-~1230	~136	5	95	100
>176,000	>~1230	0	100	0	100

The total amount of support is HUF 125 billion and the eligible area is up to 4.9 million hectares. Since October 16, 2017, advance payment amounts may not exceed HUF 17,643 per hectare. The regulations set out three practices that must be fulfilled to pay for greening. One of these is that farmers with over 15 hectares of arable land should have an ecological target area of 5% of their arable land. These areas are also referred to as ecological focus areas (EFA). A short rotation woody energy plantation can be eligible as an EFA area if they are free of fertilizers and pesticides. Additionally, only the ten tree species defined by law can be planted.

The "VP5- 8.1.1-16 Support for Afforestation" (2016-2019) application is a non-refundable grant of EUR 1.640-2.216 per hectare for the establishment of an industrial woody plantation. Furthermore, optional additional activities include the establishment of electric fences (4.8 EUR/m) and fences (5.8 EUR/m) if appropriate conditions are met. The smallest eligible area with the crown area is 0.5 hectares. With industrial woody plantations, the requirement to pay the subsidies exist. This requirement is the sale of more than 50% of the timber production for industrial purposes within, at the latest, 20 years. In the announcement, special attention is drawn to the range of ineligible activities, including the establishment of woody and short rotation plantations for energy purposes.

3.3. Impact of changes in legislation and support on plantations

According Forestry Directory of NÉBIH data, the size of plantations established in Hungary is 4,351 ha. The majority, about 80%, of these plantations are poplar because this species is the most suitable for utilizing the available areas [28]. Willow accounts for 7.4% of the total area of plantations and 7% of robinia plantations. With regard to cultivation technology, the majority of plantations have a coppicing technology, because the former legislation has advocated of planting of willow, poplar and robinia species in a coppicing mode.

Earlier practice shows a number of plantations that were unreported the Forestry Directory of NÉBIH. Consequently, these did not appear on the register. Conversely, many discontinued plantations still appear on the register [25]. In an effort to avoid this in the future, the forest authority must be informed about the harvesting and elimination of woody plantations using the NÉBIH standard form according to the 135/2017. (VI. 9.) Government Regulation.

The economical planting and maintenance of energy plantations can only be realized in areas with favourable habitat conditions [29]. However, in recent years willingness to establish plantations in these areas has dropped due to the lack of support schemes. Between 2007 and 2013, financial support (additional for energy crops) offered through the 72/2007 (VII. 27.) Ministry of Agriculture Decree (ÚMVP) encouraged farmers to plant. With the lack of support and the appearance of the draft for the support of industrial plantations in 2016, energy plantation planting was barely realized (Figure 2).

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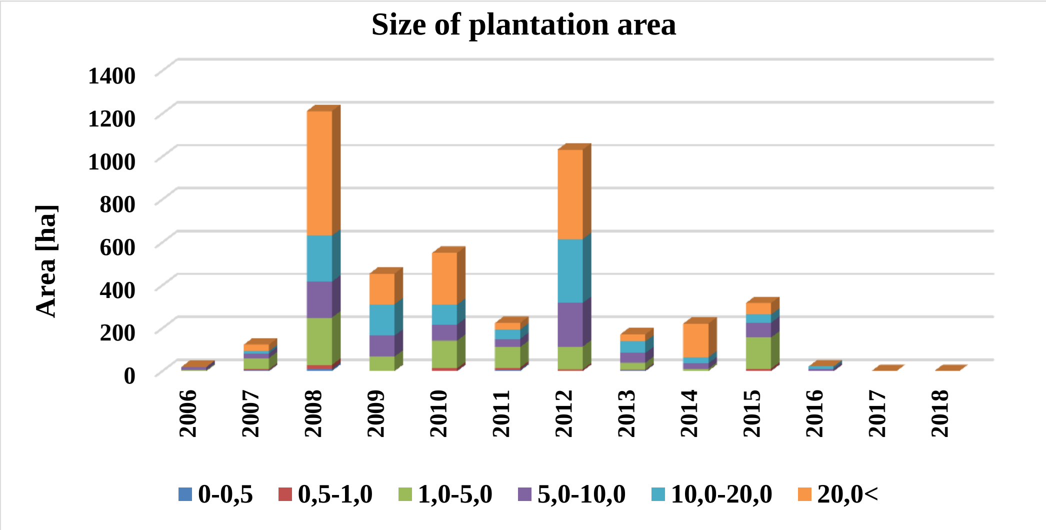

Figure 2. Area of established plantations [ha] depending on available support [based on the data of NÉBIH]

A look at the size sharing of the plantations reveals they also follow the requirements of the supports. The 72/2007 (VII. 27.) Ministry of Agriculture Decree only provided support for plantations over 1 ha. As a result, planting areas increased from between 1.0–5.0 ha. This shows farmers most often choose the smallest planting area, which is already possible according to the support form, in some cases the medium (5-10 ha) plantations, see Fig. 3. The small planting area choose is primarily due to the minimization of risk factors. Occasionally, after a successful planting, the farmers were more courageous in establishing further plantations.

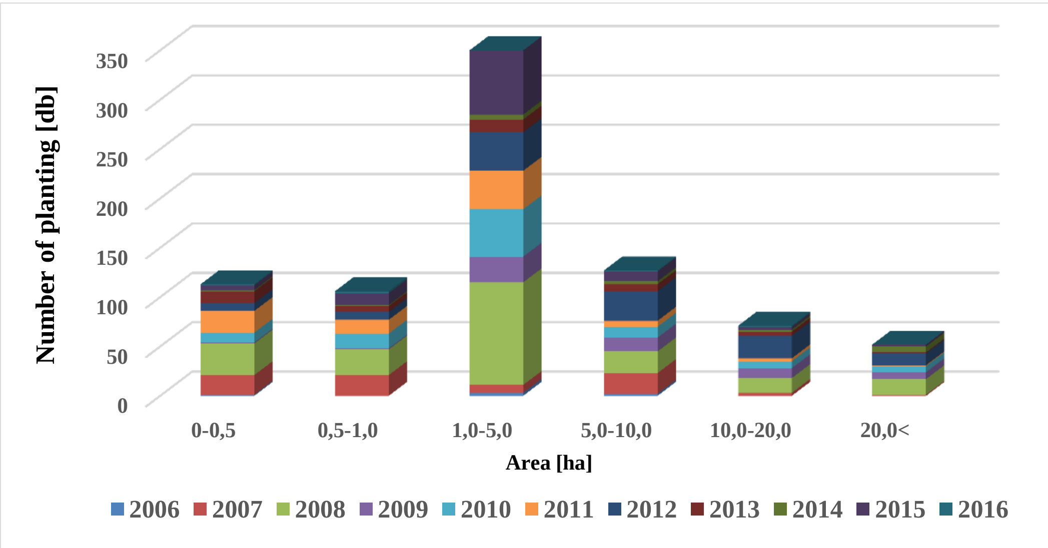

Figure 31. Number of plantation establishments depending of typical size [based on the data of NÉBIH]

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From the perspective of economical machine utilization, the optimum plantation size can be a few dozen hectares, which do not have to be connected in all cases. Additionally, they do not have to belong to a same owner, but need to be fit into an integration system for economic reasons [30]. Therefore, we also examined the size of the total area of plantations belonging to each settlement.

The results give a far more favourable picture of a potential investment project. Plantations of under 10 ha exist near 77 settlements; plantations between 10-50 ha, near 47 settlements; and plantations over 50 ha, near 22 settlements. The settlements with outstanding plantations size are located mainly in Veszprém and Baranya counties, both of which have a purchaser (large power plants). Plantation near secure markets can be operated economically [25].

The average purchase price of the wood chips from plantations is 20,000 HUF/odt, which was the price Pannon Power Plant paid last year [29]. According to Posza (2018), in addition to the actual incurred costs, the cost of the raw material production is higher than the transfer price, apart from the various possible support and land rent [29].

Nonetheless, there is an interest in the district of large power plants without support. Only two power plants in the country have had plantations established near them since 2012, as shown in Figure 4.

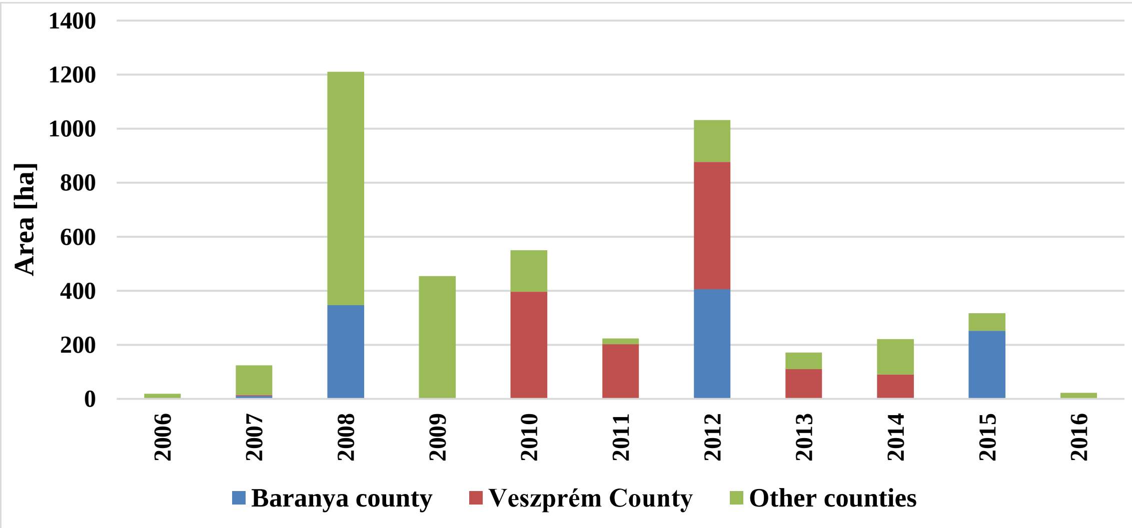

Figure 4. The size of plantations in counties with high buying capacity [based on the data of NÉBIH]

The first and most important aspect during plantation planning is to select a site with a high local feedstock.

4. CONCLUSIONS

New legislation addresses woody energy plantations in a more transparent manner and establishes a new plantation category. In some cases, the cutting cycle has been lengthened. Site exploration and the related expert consulting has been made obligatory before planting, and the list of usable wood species has been expanded. The recent changes, which have eliminated the direct and indirect support of short rotation coppices (SRC), leaving only area-based and greening-related support, has significantly reduced the willingness of farmers to establish SRC in Hungary. The support of roundwood plantations for industrial purposes, which have been available since 2016, did not increase farmer willingness to plant, as NÉBIH. At the same time, plantations were established close to the secure markets with buyers like Pannon Power

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Plant and Bakonyi Power Plant because the wood chips from plantations play a significant role in the supply of raw materials to power plants.

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